John Crawford

M. D.

ELEMENTS
OF
NATURAL HISTORY,
AND OF
CHEMISTRY:

BEING THE SECOND EDITION OF
THE ELEMENTARY LECTURES ON
THOSE SCIENCES,

FIRST PUBLISHED IN 1782,

AND NOW
GREATLY ENLARGED AND IMPROVED,

BY THE AUTHOR, *M. DE FOURCROY*,

DOCTOR OF THE FACULTY OF MEDICINE AT PARIS,
OF THE ROYAL ACADEMY OF SCIENCES, &c. &c. &c.

TRANSLATED INTO ENGLISH.

WITH OCCASIONAL NOTES, AND AN HISTORICAL
PREFACE, BY THE TRANSLATOR.

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Crawford

THE

TRANSLATOR's PREFACE.

THE importance of chemical knowledge to ſociety, and the favourable reception which the following work has met with among our enlightened neighbours, render it unneceſſary to mention the motives that have cauſed an Engliſh tranſlation to be undertaken. A very few words will likewiſe be ſufficient to explain the manner in which I have endeavoured to perform my duty as tranſlator. The original has been as cloſely followed as the genius of the two languages would permit; and in ſuch places, as a greater liberty has been taken, it will be invariably found, that the ſingle purpoſe of adhering with fidelity to the author's meaning has been ſtrictly kept in view. I have likewiſe added ſome Notes, which I hope will be found uſeful. In theſe I thought it incumbent on me, as the book is intended for beginners, to avoid all controverſial remarks on the theoretical doctrines contained in the text: neither did I ſuppoſe it at all neceſſary that I ſhould enter into hiſtorical diſcuſſion. But as it is certain, that the want of a ſpeedy and faithful communication of philoſophical diſcoveries between Great

Britain and the Continent, together with the unprincipled conduct of ſuch perſons as are daily employed in endeavouring to appropriate to themſelves the diſcoveries of others, have produced many hiſtorical miſtakes: and on the other hand, as among the variety of new theories of chemiſtry, offered to the public, few have been exhibited with a proper diſcrimination between hypotheſis and matter of fact; I preſume that a ſhort account of ſome of the principal changes, the ſcience of chemiſtry has undergone of late years, will not be unacceptable.

In the infancy of the true philoſophy, when the ſame men who had been taught the logomachia of the ſchools began to draw inferences, and to reaſon from the things around them, it is not to be wondered that their reliance on the power of the human mind was greater than it ought to have been, and that they were not aware of the neceſſity of often recurring to the teſt of experiment, in order to detect the unwarranted concluſions we are continually making. A few firſt principles, poſſible indeed, but not proved, were aſſumed by the great Des-Cartes as a foundation for a complete theory of the univerſe. From theſe he deduced ſuch facts as were known in his time. The facility with which the author of a favourite hypotheſis can adapt the facts to it, was not then known; and therefore he thought it a good argument to urge his ſucceſs,* as a proof of the truth of his principles. The philoſophers, who have ſucceeded him, have been but too much inclined to follow his example. Where the principles exiſting in nature are but few, as is the caſe with mechanics, the greateſt ſucceſs has followed the application of ſtrict mathematical reaſoning to thoſe principles; but in chemiſtry, where they are perhaps numerous, and certainly in many reſpects unknown, the imperfect theories, and the numerous paralogiſms, with which the writings of philoſophers are filled, often induce the cautious reader to wiſh that they had been either leſs ready in making their inferences, or more attentive to the ſtrict verification of them by experiment.

The operations of chemiſtry, taken in a looſe and general ſenſe, conſiſt in the producing changes in bodies, either by heating them, or by preſenting them to other fluid bodies, with which they form an union. And as combuſtion is the moſt uſual means of raiſing the temperature of bodies, the moſt important part of chemical ſcience muſt conſiſt in a knowledge of what happens in that wonderful proceſs. The early chemiſts among the moderns, borrowing their terms from ſuch ſubſtances as appeared eminently to poſſeſs certain properties, ſuppoſed combuſtibility to depend on a ſulphur contained in bodies. This opinion was rectified, and generalized by Beccher, and afterwards by Stahl; their doctrine being ſimply, that combuſtible bodies contain a principle called phlogiſton, which uninflammable bodies do not, and that combuſtion conſiſts in the eſcape of this principle.

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* Sed qui advertent quam multa de magnete, de igne, de totius mundi fabrica, ex paucis quibuſdam principiis hic deducta ſint; quamvis iſta principia tantum caſu & ſine ratione à me aſſumpta eſſe putarent, forte tamen agnoſcent, vix potuiſſe contingere, ut tam multa ſimul cohererent ſi falſa eſſent. Principia ſub fine.

The opinion, that a principle eſcaped from bodies during combuſtion, coincided perfectly with the common notions derived from the aſcent of ſmoke, flame, &c. and the comprehenſive and truly philoſophical genius of Stahl, was applied in adapting it, with ſo happy a facility, to the leading phenomena of chemiſtry, that it became univerſal throughout Europe. Difficulties were indeed urged againſt it, the chief of which were, that the principle of inflammability had never been exhibited alone, and that ſuch bodies as did not emit vapours in ſenſible quantities, were found to be augmented, inſtead of diminiſhed in weight, by the imaginary loſs of one of their principles. But theſe were ſuppoſed to be removed, by the obſervation that phlogiſton never quitted an inflammable body, but to unite with another of the uninflammable claſs; and the additional weight, gained ed by calcined metals, was by ſome ſuppoſed to conſiſt in the matter of fire, and by others to ariſe from the property of abſolute levity, which they attributed to phlogiſton.

The numerous diſcoveries of Dr. Prieſtley have directed the attention of philoſophers to the properties of bodies in the aerial or permanently elaſtic ſtate; and in the rich harveſt of diſcovery which has followed, that great man has continued to maintain the preeminence in which his firſt fame originated. It was from his experiments that Mr. Kirwan deduced the opinion that inflammable air, in a ſtate of combination, is the very ſubſtance to which all the characters and properties of the phlogiſton of the ancient chemiſts belong; and this opinion was rendered ſtill more probable by a ſubſequent ſeries of experiments, in which Dr. Prieſtley revived metallic calces, by heating them with a burning glaſs in inflammable air.

A conſiderable number of modern philoſophers had obſerved the neceſſity of air to maintain combuſtion; but Dr. Prieſtley firſt made experiments directed to this object. His capital diſcovery of pure, vital, or dephlogiſticated air, is of the higheſt value.[*]

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[*] Dr. Prieſtley diſcovered this air on the firſt of Auguſt 1774, (ſee his 2d vol. p. 34.) and aſcertained its properties in the courſe of the following year. The celebrated Scheele, whoſe loſs is ſeverely felt by the ſcientific world,

M. Lavoiſier is the firſt who, by direct and accurate experiments, proved that the weight gained by metals in calcination, correſponds with that of the air they abſorb. This circumſtance, together with the diſcovery of the compoſition of water, ſeems to have given the doctrine of phlogiſton a ſhock, at leaſt equal to the advantage it derived from the diſcovery of the revival of metallic calces by inflammable air. For it was an inference eaſily made, that if metals, and other ſubſtances, were admitted to receive air in calcination, and to recover their inflammability by giving it out, it was unneceſſary to ſuppoſe a principle of inflammability.

The powers of nature, which are ever the ſame, and are continually performing their operations before us, whether we underſtand them or not, often preſent facts of the utmoſt value and importance, which we overlook, or regard with indifference. Hence it happens, that when an enlightened obſerver makes any diſcovery, it is almoſt always

made the ſame diſcovery before the middle of the year 1775, Dr. Prieſtley's book not being then publiſhed. Scheele's treatiſe on air and fire was not publiſhed till the latter part of the year 1777. There is no doubt but theſe two great philoſophers made their diſcoveries independent of each other, and without the knowledge of the obſcure hints reſpecting this kind of air, which John Mayow gave, almoſt a century before. Conſult pages xiii. and xl. of the preliminary matter to the Engliſh tranſlation of Scheele's Chemical Obſervations on Air and Fire, by J. R. Forſter, L.L.D. &c.

obſerved that ſomebody has ſeen the fact before him, or given ſome confuſed hints reſpecting its theory. It is evident, however, that the firſt diſcoverer, if there be any merit in diſcovery, is not the man who finds the treaſure, and ſuppoſes it to be none; but him who is conſcious of its value, and applies it to uſe. On theſe principles it is, that the claims of the diſcoverers of the compoſition of water muſt be eſtimated. The facts appear to be as follow.

Previous to the month of October 1776, the celebrated Macquer, aſſiſted by M. Sigaud de la Fond, made an experiment by burning inflammable air in a bottle, without exploſion, and holding a white china ſaucer over the flame. His intention appears to have been that of aſcertaining whether any fuliginous ſmoke was produced; and he obſerves that the ſaucer remained perfectly clean and white; but was moiſtened with perceptible drops of a clear fluid, reſembling water, and which in fact appeared to him, and his aſſiſtant, to be nothing but pure water. He does not ſay whether any teſt was applied to aſcertain this purity, neither does he make any remark on the fact.*

In the month of September 1777, Meſſrs. Bucquet and Lavoiſier, not being acquainted with the fact, which is incidentally and conciſely mentioned by Macquer, made an experiment to diſcover what is produced by the combuſtion of inflammable air. They fired five or ſix pints of inflammable air in an open and wide-mouthed bottle, and inſtantly poured two ounces of lime-water through the flame, agitating the bottle during the time the combuſtion laſted. The reſult of this experiment ſhewed that fixed air was not produced.*

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* Dictionaire de Chymie, 2d Edition, Paris, 1778, Art. Gas Inflammable, Vol. II. p. 314, 315.

Before the month of April 1781, M. John Warltire, encouraged by Dr. Prieſtley, fired a mixture of common and inflammable air in a cloſe copper veſſel, and found its weight diminiſhed. Dr. Prieſtley likewiſe, before the ſame period, fired a like mixture of inflammable air and common air, and alſo of inflammable air and dephlogiſticated air, in a cloſed glaſs veſſel, Mr. Warltire being preſent. The inſide of the veſſel, though clean and dry before, became dewy, and was lined with a ſooty ſubſtance.† Theſe experiments were afterwards repeated by Mr. Cavendiſh, and by Dr. Prieſtley, and it was found that the diminution of weight did not take place, neither was the ſooty matter perceived.‡

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* Acad. Par. 1781, p. 470.

† Prieſtley, V. 395.

‡ Phil. Tranſ. LXXIV. 126. Dr. Prieſtley ſuppoſed the ſooty matter to be part of the mercury uſed in filling the veſſel. Phil. Tranſ. LXXIV. 332.

Theſe circumſtances, therefore, muſt have ariſen from ſome imperfection in the apparatus or materials, with which the former experiments were made.

It was in the ſummer of the year 1781, that Mr. Henry Cavendiſh was buſied in examining what becomes of the air loſt by phlogiſtication, and made thoſe valuable experiments which were read before the Royal Society on the 15th of January, 1784.* He burned 500000 grain meaſures of inflammable, with about 2½ times the quantity of common air, and by cauſing the burned air to paſs through a glaſs tube, eight feet in length, 135 grains of pure water was condenſed. He alſo exploded a mixture of 19500 grain meaſures of dephlogiſticated, and 37000 of inflammable air, in a cloſe veſſel. The condenſed liquor was found to contain a ſmall proportion of nitrous acid, when the mixture of the air was ſuch that the burned air was not much phlogiſticated. This great philoſopher, who may be conſidered as the true diſcoverer of the compoſition of water, appears to think, with Mr.

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* Mr. Lavoiſier relates, that Dr. Blagden, Sec. R. S. (who was preſent at the performing of the capital experiment of burning inflammable and dephlogiſticated air in a cloſed veſſel on the 24th June, 1783) informed him, that Mr. Cavendiſh had already done the ſame thing, and obtained water. See the Memoirs of the Royal Academy at Paris, for 1781, p. 472. alſo Phil. Tranſ. vol. lxxiv. p. 134.

Watt, that in thoſe experiments of Dr. Prieſtley's, in which the vitriolic and nitrous acids ſeemed to be converted into dephlogiſticated air, the acids ſerved only to decompoſe the water by depriving it of its phlogiſtic part; but he thinks it unneceſſary to include the conſideration of elementary heat, as Mr. Watt does, becauſe, in his opinion, it is more likely that there is no ſuch thing, and that the bringing the conſideration forward in every chemical experiment, in which increaſe or diminution of heat takes place, might occaſion more trouble and perplexity than it is worth.*

In the mean time M. Lavoiſier continued his reſearches, and during the winter of 1781—1782, together with M. Gingembre, he filled a bottle of ſix pints with inflammable air, which being fired, and two ounces of lime-water poured in, was inſtantly ſtopped with a cork, through which a flexible tube communicating with a veſſel of dephlogiſticated air was paſſed. The inflammation ceaſed, except at the orifice of the tube, through which the dephlogiſticated air was preſſed, where a beautiful flame appeared. The combuſtion continued a conſiderable time, during which the lime-water was agitated in the bottle. Neither this, nor the ſame experiment repeated with pure water, and with a weak ſolution of alkali, inſtead of lime-water, produced the deſired concluſion; for theſe ſubſtances were not at all altered.

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* Philoſoph. Tranſ. vol. lxxiv.

The inference of Mr. Warltire, reſpecting the moiſture on the inſide of the glaſs, in which Dr. Prieſtley firſt fired inflammable and common air, was, that theſe airs by combuſtion depoſited the moiſture they contained. Mr. Watt, however, inferred from theſe experiments, that water is a compound of the burned airs, which have given out their latent heat by combuſtion; and communicated his ſentiments to Dr. Prieſtley in a letter, dated April 26, 1783,* and he concludes, that in every caſe wherein dephlogiſticated air was produced, water has been decompoſed, by the uſe of ſome ſubſtance which had a ſtronger attraction to its phlogiſton than is poſſeſſed by the dephlogiſticated air, which is therefore ſet at liberty. He repeated ſome experiments particularly with a view to decide this point, and in ſeveral of them the quantity of dephlogiſticated air added to the acid which came over, greatly exceeded the original weight of acid employed. He diſſolved magneſia, calcareous earth, and minium reſpectively in pale nitrous acid, and on diſtilling to dryneſs, found nearly the whole of the nitrous acid in the retort, highly phlogiſticated. From common nitre the dephlogiſticated air was ſixteen times the weight of the nitrous acid which was miſſing. Mr. Watt has therefore a claim to the merit of a diſcoverer with regard to the compoſition of water, and has the advantage of priority in the diſcovery of its decompoſition.

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* Philoſoph. Tranſ. vol. lxxiv. p. 330.

It does not appear* that the compoſition of water was known, or admitted in France, till the ſummer of 1783, when M. Lavoiſier and M. de la Place, on the 24th of June, repeated the experiment of burning inflammable and dephlogiſticated air in a glaſs veſſel over mercury, in a ſtill greater quantity than had been burned by Mr. Cavendiſh. The reſult was nearly 5 || gros of pure water. M. Monge made a ſimilar experiment at Paris, nearly at the ſame time, or perhaps before.

The theory which has been propoſed and explained by M. Lavoiſier, wherein ſuch phenomena as chemiſts have uſually accounted for by the diſengagement or tranſition of phlogiſton, are explained, merely by the engagement or contrary tranſition of dephlogiſticated air, or its baſe, by him called

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* Compare Phil. Tranſ. vol. lxxiv. p. 138. with the Memoirs of the Royal Academy at Paris for 1781, pages 472, and 474.

|| The ounce poids de marc being 472. 2 gr. troy, this quantity will be 295 Engliſh grains.

the oxyginous or acidifying principle, is amply explained in the following work. This theory received a great acceſſion from the diſcovery of the compoſition of water, as I have already remarked; for it was eaſy to attribute the inflammable air which is diſengaged in many proceſſes to the decompoſition of water, which is undoubtedly preſent in moſt of them, inſtead of ſuppoſing it to come from ſuch bodies as former chemiſts had imagined to contain the principle of inflammability. In the month of September, 1783, M. de la Place communicated to M. Lavoiſier his thoughts† on the decompoſition of water, which from M. Lavoiſier's former experiments he concluded to take place in metallic ſolutions; and theſe reaſons, added to M. Lavoiſier's own reflections, induced him to purſue the ſubject by a new ſeries of experiments.

This aſſiduous and accurate philoſopher firſt placed a quantity of iron filings and pure water in the upper part of a veſſel inverted over mercury, and obſerved that the iron became calcined, inflammable air being at the ſame time diſengaged, the water being, as he ſays, truly decompoſed.* He then proceeded, in conjunction with M. Meuſnier, to paſs the ſteam of water through a red hot iron tube, and found that the iron was calcined, and inflammable air diſengaged: and the ſteam of water being paſſed over a variety of other combuſtible or calcinable ſubſtances, produced ſimilar reſults; the water diſappearing, and inflammable air being diſengaged. Theſe capital experiments are accounted for by M. Lavoiſier, and ſuch chemiſts as do not admit the exiſtence of phlogiſton, by ſuppoſing the water to be decompoſed into its component parts, dephlogiſticated and inflammable air, the former of which is ſaid to unite with the ignited ſubſtance, while the latter is diſengaged. If it were allowable to place much dependance on the quantities of the products in experiments of this nature, wherein different philoſophers diſagree, the reſults of M. Lavoiſier, which anſwer to the proportions of the two principles determined in the compoſition of water, would add much force to his concluſions. But the advocates for phlogiſton contend, that the water unites totally with inflammable or calcinable ſubſtances, and ſets their phlogiſton at liberty. If the chemical reader will attentively peruſe the valuable papers of the Anti-phlogiſtians in the Journal de Rozier, and the Memoirs of the Royal Academy at Paris, and compare them with Kirwan's Treatiſe on Phlogiſton, Dr. Prieſtley's 6th volume of Experiments and Obſervations, and more eſpecially with the latter part of Mr. Cavendiſh's paper in the

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† Memoirs of the Royal Academy at Paris, 1781, p. 476.
* Ibid. 1781, p. 271.

74th volume of the Philoſophical Tranſactions, which is a maſter-piece of preciſion and clearneſs, he will ſee that the deductions reſpecting the exiſtence or non-exiſtence of phlogiſton in the ſenſe of Stahl, are very far from being concluſive, becauſe deciſive experiments are wanting. He will alſo perceive, that the nomenclatures of the old and new chemiſtry, founded on their reſpective theories, are ſo interwoven into the relation of matters of fact, as to have produced numberleſs paralogiſms on either ſide; and that nothing is eaſier, in general, than to account for chemical phenomena either way.

When the extenſive nature of chemical ſcience is attended to, we have more reaſon to admire the rapid ſucceſs of our co-temporaries, than to cenſure their errors; but ſilence is equally blamable, becauſe it tends to perpetuate them. I ſhall therefore conclude this preface by obſerving, that I have not, in the ſubordinate, though uſeful, office of tranſlator, been forgetful of that reſpect which is due to the writer, whoſe work I have thought proper to turn into Engliſh. I have advanced no opinions of my own; neither have I indecently controverted his poſitions. It appeared neceſſary to ſtate the facts I have here mentioned, and it will be ſeen that I have ſtated them with fidelity. And as I have diſplayed none of that mean national partiality, which combined with the difficulty of acquiring a perfect knowledge of what paſſes in foreign countries, too often produces miſrepreſentations of facts, I am perſuaded that the candid among our neighbours, as well as the learned author himſelf, will receive it with a proper degree of liberality.

LONDON, Dec. 13. 1787.

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PRELIMINARY DISCOURSE.

Containing a ſhort Account of the Nature and Properties of Elaſtic Fluids, and ſerving inſtead of Additions and Corrections, to the Facts and the Chemical Theory contained in this Work.

ALthough the new diſcoveries made ſince the end of the year 1781, the time of the publication of the firſt edition of this work, have rendered it neceſſary to make conſiderable alterations and additions in this ſecond edition; yet the time of its going to the preſs has not admitted of the inſertion of many very important facts relative to chemical theory; more eſpecially in the places they ought properly to have occupied in the order of the work. I have therefore thought proper to give a view of the whole, that ſuch as are deſirous of entering into the ſtudy of chemiſtry may not be deprived of them. It is not my intention to give an ample detail of all the new enquiries in which modern chemiſts are engaged, becauſe they would much exceed the limits of a ſupplement, but I have not neglected any facts that conſiderably influence the theory of chemiſtry; and as ſeveral of theſe are ſuch as have even cauſed me to change my opinion with reſpect to ſome of the general theories propoſed in this work, I have thought proper to give the new facts in a connected manner, under the title of an Account of the Nature and Properties of Elaſtic Fluids.

Modern chemiſts have given the name of elaſtic fluid or gas to bodies which have the appearance of air, though they do not poſſeſs all its properties; but when the hiſtory of all permanently elaſtic fluids is attended to, atmoſpheric air is uſually comprehended amongſt them.

Since the time it has been clearly aſcertained that, in a great number of chemical operations, many of theſe elaſtic fluids are either diſengaged or fixed, the attention of philoſophers has been directed to the ſtudy of their different properties, and many attempts have been made to determine what influence their diſengagement or fixation may have on natural phenomena.

Many perſons, in other reſpects very eminent, have haſtily adopted the opinion, that theſe bodies are nothing more than common air, mixed or impregnated with different matters in a vaporous form. In conſequence of this notion, they have decidedly aſſerted that theſe fluids have been too much attended to, and that their newly diſcovered properties ought not to be conſidered as having any influence on chemical theory. We ought not to be ſurprized at finding this repugnance, and even oppoſition, amongſt the learned, to the reception of theſe new doctrines, when we reflect, that Stahl, one of the greateſt geniuſes of his age, entertained the ſame opinion reſpecting the diſcoveries of Hales on Air. This difficulty of admitting a theory ſo very different from that of the ancients, may likewiſe ariſe from the circumſtance that the greater number of the works in which this part of chemical ſcience is treated of, have not given a very accurate ſtatement of the general nature, formation, and fixation of theſe elaſtic fluids. The theory which reſpects them has not yet been clearly developed, but in ſome particular memoirs of Mr. Lavoiſier; and the hiſtory of gaſes has never yet been collected into one work. But as this ſubject is one of the higheſt importance, and relates to a great number of phenomena, which the early time of the impreſſion of the firſt volume of this work has not permitted me to inſert at that length, and with that perſpicuity it deſerves, it becomes neceſſary to conſider it in this place.

§ 1. Con-

§ 1. Concerning Light and Heat, and the Formation, Diſengagement, and Fixation of Elaſtic Fluids.

It is, at preſent, univerſally acknowledged that light is a body, exiſting independent of all other ſubſtances, and poſſeſſing its own characteriſtic properties. As to heat, the proofs of its exiſtence are not ſo well eſtabliſhed; and many philoſophers have thought that it was nothing more than a modification, which all bodies are ſuſceptible of; but the modern experiments on the different quantities of heat contained in bodies, their aptitude to abſorb, to preſerve, or to conduct heat, and the elective attractions which it ſeems to follow, render the firſt opinion concerning its exiſtence much more probable than ever; and it is certain that all the phenomena obſerved in nature, are more eaſily and naturally explained according to this opinion, than by that of Bacon. It will therefore be proper to ſhew in this diſcourſe, firſt, the reaſons which induced me to prefer this hypotheſis to that which I have adopted in the firſt volume of this work. 2dly, The modifications which this new hypotheſis muſt produce in the principal theories of chemiſtry.

The ſimple and uniform laws, by which nature appears to produce the phenomena we behold around us, ſeem to point out that there is but one body which can be conſidered as fire; for this reaſon, many modern philoſophers conſider light and heat as one ſingle fluid, as pure fire, but in two different ſtates; it is light when the particles collected together, and in poſſeſſion of their whole attractive force unſaturated, are projected with immenſe velocity; it is heat when theſe ſame particles diſperſed, and divided more ſlowly, and with a tendency to equilibrium. According to this theory, heat may become light; and light, on the other hand, may become heat, when this motion is rendered ſufficiently ſlow. It cannot, however, be denied that light often produces effects very different from thoſe of heat, as is ſeen in the nitrous acid, aerated muriatic acid, metallic calces, and the leaves of vegetables; all which give out vital air when expoſed to the ſun's rays, though heat alone has no effect in diſengaging that fluid from them. Thus it is likewiſe found that the light of the coals, which paſſes through veſſels ignited in the fire, changes the nature of the products, as was firſt obſerved by myſelf in the former edition of this work. Modern chemiſts admit heat as a principle, and inform us that all natural bodies contain different quantities of this fluid. One of the principal effects of this combined heat, which all bodies ſeem capable of containing in different quantities, in their different ſtates of aggregation, is to change and to modify the ſtates of bodies. In order to underſtand this phenomenon, it muſt be obſerved, that there are two kinds of heat, or rather, that heat itſelf exiſts in two different ſtates in all natural ſubſtances; the one a ſtate of intimate combination, in which heat is called latent, becauſe it is not ſenſible; the other ſtate is that in which it is ſimply diſſeminated: heat in this laſt ſtate may be driven out by preſſure alone, or by mechanical means. Thus it is that when a bar of iron is ſtruck, and its particles are by that means made to approach each other, part of its heat eſcapes in the ſame manner as water iſſues out of a wet ſpunge. Heat, in a ſtate of true combination, does not leave the body it is combined with, but in conſequence of new chemical combinations. All ſolid matters, which contain theſe two kinds of heat, are capable of receiving a greater quantity both of one and of the other, and the additional quantity cauſes the particles to recede more and more from each other. Its firſt effect is the ſoftening of the ſolid body; its ſecond, in proportion as its quantity becomes greater, is fuſion or liquefaction; its third, ſtill ſuppoſing an augmentation of quantity, is the production of elaſtic fluidity. Thus water in the form of ice is ſoftened by a certain degree of heat, as appears by its being leſs elaſtic; a greater degree of heat melts it; and laſtly, it becomes ſtill more fluid, if the term may be uſed, when a ſtronger degree of heat reduces it into vapour: ſo that the vapour of water may be ſaid to contain a total ſum of heat, conſiſting of the quantity neceſſary to conſtitute ice of a certain denſity, added to the quantity neceſſary to produce the ſtate of liquidity; and laſtly, the quantity neceſſary to maintain the ſtate of elaſtic fluidity.

This general theory may be applied to all the bodies in nature; there is no one which may not be conſidered as capable of paſſing through all theſe ſtates by the aſſiſtance of a ſufficient degree of heat, and as far as relates to this property, they do not appear to differ from each other, but in the quantities of heat neceſſary to produce the changes reſpectively in each. It is for want of a ſufficient degree of heat, that rock cryſtal can neither be melted *, nor brought into the vaporous ſtate; and it is no more difficult to conceive the poſſibility

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* See note on p. 217. vol. I.

of this being effected, than it is to conceive that the fluid we always ſee in a ſtate of elaſticity, namely, the air may acquire a great degree of ſolidity, as in fact happens in many combinations.

It is eaſy on theſe principles to explain the formation of elaſtic fluids, which takes place whenever bodies receive and abſorb ſufficient quantities of heat. All aeriform fluids owe their elaſtic property to the matter of heat; but the preſſure of ſurrounding bodies, and more eſpecially that of the air, is required to be removed or diminiſhed before this ſtate of extreme dilatation can take place, and if the weight of the atmoſphere be entirely removed, as happens in the vacuum of the air pump, a body at a much lower temperature than would have been neceſſary to have produced the elaſtic ſtate in the open air, may immediately become elaſtic. This accounts for the more rapid evaporation which takes place on lofty mountains, and hence we may perceive the neceſſity of mentioning in the account of experiments, at what degree of external preſſure bodies have taken the form of elaſtic fluid, or at leaſt the degree of preſſure under which they can preſerve it. For it muſt be obſerved, that all bodies capable of taking this ſtate of elaſtic fluidity are not equally diſpoſed to preſerve it, and that in this reſpect the differences between them are ſo great, that they have been diſtinguiſhed into permanent and non-permanent. The former remain elaſtic during a very long ſpace of time, and till ſome combination takes from them the matter of heat neceſſary to maintain their ſtate; the ſecond, which are denoted by the name of vapour, loſe the elaſtic fluidity by a degree of preſſure or refrigeration eaſy to be determined, and give out to all the ſurrounding bodies the matter of heat, which maintains their aeriform ſtate: ſuch are water, ſpirits of wine, ether, acetous acid, &c.

After theſe details it muſt be obſerved, firſt, that every elaſtic fluid is compounded of a baſe more or leſs ſolid, and the matter of heat. Secondly, that each of theſe baſes require more or leſs heat to reduce them into the ſtate of vapour or elaſtic fluid; and that it is doubtleſs in conſequence of theſe properties that all elaſtic fluids differ from each other in their ſpecific gravity, elaſticity, &c.

Mr. Lavoiſier has explained this theory in a very perſpicuous manner, in a memoir printed among thoſe of the academy in 1777.

Though we have divided elaſtic fluids into permanent and non-permanent, it muſt be obſerved, that this diſtinction does not really exiſt in nature, that it relates only to the heat and degree of preſſure which are experienced in our climates, and in moſt of the habitable parts of the globe; and that if the cold and preſſure were more conſiderable, thoſe fluids, which are now taken to be the moſt permanent, would ſoon ceaſe to be ſo; and in the ſame manner, for the contrary reaſon, ether and ſpirit of wine would become permanently elaſtic fluids at a certain height in the atmoſphere, or at the high temperatures of certain climates, ſituate beneath the equator, &c.

The matter of heat, which contributes to the formation of permanently elaſtic fluids, is intimately combined with them, or latent, and does not become ſenſible, till theſe bodies loſe this fluidity by combining with other ſubſtances. This phenomenon is a conſequence of the general law we have eſtabliſhed, that all bodies when they become more denſe, ſuffer their heat to eſcape. Whenever an aeriform fluid or gas combines in ſuch a manner as to become liquid or ſolid, it loſes a great quantity of the matter of heat it before contained, and in order that it may paſs to this ſtate of denſity, it is neceſſary to preſent a body which has a greater affinity with its baſe than that baſe has with heat. Such in general is the cauſe of the fixation of elaſtic fluids; it may be further obſerved, that each of theſe fluids loſes or ſuffers the diſengagement of different quantities of heat, accordingly as it becomes more or leſs ſolid in its new combination, or accordingly as that combination is capable of retaining more or leſs ſpecific heat. This obſervation ſerves to explain the difference between the ſeveral kinds of combination, which are more or leſs rapid, accompanied with greater or leſs heat, and leave reſidues of various degrees of ſolidity, according to circumſtances.

Laſtly, If preſſure and cold be the two means of condenſing all elaſtic fluids, we may, perhaps, by employing ſtrong degrees of both, ſucceed in cauſing them to loſe their gaſeous ſtate, and obtain the baſes ſeparate and pure, by excluding the matter of heat which kept them in ſolution. By this means we ſhould become acquainted with the baſes of vital air, of mephitis, of inflammable air, &c. This has already been done with ſucceſs in one inſtance by Mr. Monge, who has reduced the ſulphureous gas to a ſtate of liquidity by the application of a great degree of cold.

§ 2. Concerning the methodical Diviſion or Claſſification of permanently Elaſtic Fluids.

The permanently elaſtic fluids are ſo numerous, as to render it neceſſary to claſs them methodically, or to diſpoſe them in ſuch order as may ſhew their reſpective ſimilarity or differences.

I divide theſe fluids into four claſſes. In the firſt, I place thoſe which are capable of maintaining combuſtion and reſpiration; in the ſecond, thoſe which cannot maintain either of theſe proceſſes, and are not of a ſaline nature; the third contains the ſaline gaſes; and the fourth the inflammable gaſes. All the elaſtic fluids hitherto known, are arranged in the following tables, according to this method of diſpoſition.

1ſt CLASS.

Elaſtic fluids capable of maintaining combuſtion and reſpiration.

Species I. Vital air.
II. Atmoſpheric air.

2d CLASS.

Elaſtic fluids which are incapable of maintaining combuſtion or reſpiration, and are not of a ſaline nature.

Species III. Mephitis.
IV. Nitrous air.
V. Aerated marine gas, or dephlogiſticated marine acid gas.

3d CLASS.

Elaſtic fluids which are incapable of maintaining combuſtion or reſpiration, and which are of a ſaline nature.

Species VI. Cretaceous acid gas or fixed air.
VII. Sulphureous acid gas.
VIII. Fluor acid gas, or ſparry acid.
IX. Muriatic acid gas.
X. Alkaline gas.

4th CLASS.

Elaſtic fluids incapable of maintaining combuſtion or reſpiration, and which are inflammable.

Species XI. Aqueous inflammable gas, or pure inflammable gas.
XII. Hepatic gas.
XIII. Phoſphoric gas.
XIV. Mephitized inflammable gas.
XV. Cretaceous inflammable gas.
XVI. Carbonaceous inflammable gas.

§ 3. Concerning the Nature and principal Characters of the ſeveral Kinds of Elaſtic * Fluids.

1. Vital air, called by its diſcoverer, Dr. Prieſtley, dephlogiſticated air, and by ſome other Engliſh writers empyreal air, or

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* Part of the following conſiſts of repetitions of ſome part of the work itſelf, but it ſeemed deſirable to bring them together in one point of view, and to connect them with facts diſcovered ſince the printing of the work. Theſe newly diſcovered facts are more particularly enlarged on in the preſent diſcourſe.

the principium ſorbile, is now obtained from a variety of ſubſtances. Precipitate per ſe or calx of mercury, red precipitate or mercury calcined by the nitrous acid, the precipitates of different mercurial ſalts by cauſtic alkalis, minium moiſtened with nitrous acid, nitres with alkaline or earthy baſes, lunar nitre, manganeſe, either alone or moiſtened with vitriolic acid, the dephlogiſticated marine acid of Scheele, or aerated marine acid of the French chemiſts, acetated mercury, arſenicated zink afford this fluid in various quantities by the action of light and heat, its diſengagement being manifeſtly owing to this laſt agent. It does not exiſt entire in all theſe bodies, as in fact they contain nothing more than its ſolid baſe, which is melted by the heat, and put into the ſtate of elaſtic fluidity; the metallic calces being revived in proportion as this fluid is diſengaged. Vital air is likewiſe obtained from the leaves of plants immerſed in water impregnated with the cretaceous acid, and expoſed to the contact of the ſun's rays.

Vital air is often mixed with a ſmall quantity of mephitis. This fluid, when obtained from precipitate per ſe or manganeſe, and by means of the leaves of plants, does not contain mephitic air.

Vital air is rather heavier than the air of the atmoſphere. It is the only elaſtic fluid capable of maintaining combuſtion, and is three times as effectual as atmoſpheric air in this proceſs. That is to ſay, a body which requires four cubic feet of atmoſpheric air to be completely burned, will require no more than one cubic foot of vital air for the ſame purpoſe. Combuſtion in this laſt fluid is made with an exceſſive heat and light: theſe two phenomena ariſe from the rapid ſeparation of fire, which quits the baſe of this air, in proportion as the baſe itſelf becomes fixed in the bodies which are burned. There are inſtances of combuſtions effected by this air, wherein heat only, and not light, is diſengaged. This takes place when the diſengagement is made ſlowly and ſucceſſively, ſo that the matter of fire does not move with great rapidity. Vital air is equally effectual in the proceſs of reſpiration; but as a great quantity of heat is diſengaged, it ſhould ſeem that this high degree of purity would be productive of noxious effects in the animals which reſpire it, by rarefying the blood too much, and augmenting the rapidity of its circulation.

The baſe of vital air combined with charcoal, with ſulphur, with phoſphorus, with mephitis, with a particular oil, with arſenic, &c. conſtitutes the cretaceous or carbonaceous, the vitriolic, the phoſphoric, the nitrous, the ſaccharine, and the arſenical acids. From this property it is that Mr. Lavoiſier calls its baſe the oxyginous principle; and Mr. De Morveau, the acidifying principle. It muſt be obſerved, firſt, that theſe combinations do not always take place when the combuſtible bodies are plunged cold into vital air, and that it is neceſſary at leaſt for their rapid production, that the temperature be more or leſs elevated; ſecondly, that this baſe, or oxyginous principle, enters in different proportions into the compounds, in order to produce a complete ſaturation; and that the compounds are different according to the quantities of the component parts; thirdly, that its affinity for theſe different ſubſtances is not the ſame in all, ſo that phoſphorus takes the oxyginous principle from the arſenic acid, and charcoal takes it from the phoſphoric acid, &c. Fourthly, that when this principle paſſes from one of the bodies, in which it was fixed and unelaſtic, into another, a kind of ſlow combuſtion takes place, which is not attended with light, becauſe the oxyginous principle is in the ſtate of privation of the greateſt part of its fire.

The baſe of vital air, or the oxyginous principle, united to the baſe of inflammable gas, conſtitutes water, and compounded with metals forms metallic calces; charcoal decompoſes water and metallic calces, becauſe it has a greater affinity with the oxyginous principle, than the latter has with inflammable gas and metals.

Vital air diſcolours vegetable and animal ſubſtances; when abſorbed by fat oils, it thickens them, and cauſes them to approach the ſtate of wax; in combination with the muriatic acid, and the acid of vinegar, it forms the aerated or dephlogiſticated muriatic acid and radical vinegar.

The ſtrong light of the ſun has the property of diſengaging the oxyginous principle in the form of vital air, from many of its combinations, as the calces of mercury, the nitrous acid, &c.

II. Atmoſpheric air, or common air, is a compound of the vital air before deſcribed, and mephitis; 100 parts of this air contains 72 parts of mephitis, and 28 parts of vital air. Hence it will eaſily be underſtood, why no more than one fourth of a given quantity of vital air is abſorbed during combuſtion; and likewiſe why the phenomena of combuſtion is effected in this atmoſpheric air more ſlowly, and with the diſengagement of a leſs quantity of heat and light than in vital air. But it muſt be likewiſe obſerved, that there is not perhaps any kind of combuſtion in which the 28 parts of vital air are entirely abſorbed and fixed in the combuſtible body: and that the aeriform reſidue of the atmoſpheric air, which has ſerved the purpoſe of combuſtion, never conſiſts of pure mephitis; even in ſuch caſes as the body burned remains in a fixed and ſolid ſtate, and does not all mix with the elaſtic fluid; and much leſs is the mephitic reſidue in a ſtate of purity, when the bodies burned under veſſels filled with atmoſpheric air give out a reſidue in the permanent aeriform ſtate, as charcoal, and all the organic matters which contain that ſubſtance, do. A great number of bodies alter the atmoſpheric air, and abſorb vital air. We are not yet acquainted with any bodies which have the property of renewing and purifying the air of the atmoſphere, except the leaves of vegetables, which pour out vital air diſengaged from the cretaceous acid and water, by the decompoſition effected in conſequence of the action of the ſun's light.

III. The mephitis, which exiſts in great quantities in the atſmoſphere, is diſtinguiſhed by this peculiar name by Mr. Lavoiſier, becauſe it very quickly deſtroys animal life, and extinguiſhes combuſtion; and likewiſe, becauſe this name has not yet been uſed, except very generally, without being applied to any ſubſtance in particular. It is the ſame elaſtic fluid which Dr. Prieſtley called phlogiſticated air, becauſe he thought that it was nothing but air altered by phlogiſton, diſengaged from bodies in combuſtion, or from odoriferous bodies; or in ſhort, by all the operations of nature and art, which he calls phlogiſticating proceſſes.

But it is now aſcertained, that this fluid exiſts ready formed in the atmoſphere, and is developed in proportion as the vital air is abſorbed. Modern philoſophers have made the moſt important diſcoveries reſpecting this elaſtic fluid: there are ſeveral means of procuring it in a ſtate of purity, but the proceſs uſually employed conſiſts in that of expoſing liver of ſulphur in the liquid ſtate to a given quantity of atmoſpheric air under a glaſs veſſel. The liver abſorbs the vital air by degrees, and when the abſorption is complete, the pure mephitis remains. Mr. Scheele is the inventor of this proceſs. Mephitic air is likewiſe obtained, according to the diſcovery of Mr. Berthollet, by treating muſcular fleſh, or the fibrous part of the blood well waſhed in an apparatus proper to receive the aeriform fluid which is produced: but it is neceſſary that theſe animal matters ſhould be very freſh; for if they are at all altered by putrefaction, they emit the cretaceous acid mixed with mephitis. I have diſcovered that the bladders of carp, in which Dr. Prieſtley had before obſerved noxious air, are full of this kind of fluid, and that it is eaſily collected by breaking them underneath glaſs veſſels filled with water.

Mephitis is heavier than atmoſpheric air. It inſtantly extinguiſhes a lighted taper, and very quickly deprives animals of life, when plunged in it. Mixed with vital air in the proportion of 72 to 28, it forms artificial atmoſpheric air. If it be added to the vital air in a greater proportion, it conſtitutes an elaſtic fluid noxious to animals. Neither water, earths, nor acids, have any ſenſible action on this air. Yet it ſeems capable of being abſorbed by the nitrous acid, which it renders fuming. Mr. Cavendiſh has diſcovered that 3 parts of mephitis mixed with 7 parts of vital air, and expoſed to the paſſage of the electric ſpark, is gradually condenſed, and produces the nitrous acid: an experiment which clearly exhibits the theory of the formation of this acid in the atmoſphere. Mr. Berthollet, in decompoſing the volatile alkali, either by the nitrous acid, or by the aerated muriatic acid, or in the detonation of fulminating gold, has found that the alkali conſiſts of 5 parts of mephitis, and one of inflammable air. He has likewiſe diſcovered that animal matters contain much mephitis, and that it is the combination of this mephitis with the inflammable gas, which forms the volatile alkali obtained by the action of fire, and by putrefaction; that the plants which afford this ſame ſalt by diſtillation, owe its formation to the mephitis they contain; and that they are juſtly entitled to the name of animal plants, which ſome chemiſts have given them. I have ſince aſcertained,

certained, firſt, that of all animal matters the fibrous part is that which furniſhes the greateſt quantity of mephitis, by the application of the nitrous acid; ſecond, that after putrefaction the mephitis is no longer attainable, but that a great quantity of volatile alkali is produced.

Theſe very remarkable properties of mephitis are more particularly entitled to the attention of phyſicians; they throw great light on the difference between vegetable and animal matters, on the formation of volatile alkali, on putrefaction, and on the cauſe of the production of the nitrous acid by putrid animal matters.

As this elaſtic fluid has been confounded by certain writers with the cretaceous acid, it muſt be recollected that the mephitis has neither ſmell nor taſte in any ſenſible degree, that it is not ſo heavy as this aeriform acid, that it does not redden the tincture of turnſole, nor precipitate the lime from lime-water.

IV. Nitrous gas was known to Hales; but Dr. Prieſtley was the firſt philoſopher who paid a proper attention to its diſtinctive characters. This elaſtic fluid is diſengaged during the action of a great number of combuſtible bodies on the nitrous acid; more eſpecially metals, oils, mucilages, and ſpirit of wine: it extinguiſhes flame, deprives animals of life, is neither acid nor alkaline, and is not altered by pure water; with pure air it forms again the nitrous acid, becauſe it is itſelf nothing elſe but the nitrous acid deprived of a part of the oxyginous principle, and conſequently compoſed of mephitis and the oxyginous principle, but containing more of the former, and leſs of the latter than the nitrous acid itſelf. Hence ariſes the difference between the ſeveral ſpecimens of this gas, according to the proportions of mephitis and pure air which it contains; and hence the uncertainty which eudiometric experiments are liable to. It will be eaſily underſtood from theſe circumſtances, why in many caſes, and eſpecially when a body very greedy of the oxyginous principle is employed to obtain nitrous gas, and which abſorbs much of that principle for its ſaturation, a nitrous gas is obtained, containing mephitis diſengaged, and ſometimes the product is nothing elſe but mephitis. Laſtly, it is to the ſame property of nitrous gas, that the ſingular effect of liver of ſulphur on this gas is to be attributed. A ſolution of the liver, placed under a glaſs veſſel full of nitrous gas, quickly abſorbs a part; the remainder no longer becomes red by the contact of atmoſpheric air, but maintains combuſtion better than the air of the atmoſphere: it is in fact air, ſomewhat more pure than common air; the proportion of vital air to mephitis is more conſiderable;

ble; but if the hepar be ſuffered to continue its action on the gas, all the vital air is readily abſorbed, and the reſidue is pure mephitis. We muſt likewiſe obſerve, that nitrous gas produces a green colour in flame, before it extinguiſhes it; and that in a great number of inſtances this colour is produced by ſuch aerial compounds as contain the mephitis.

Theſe leading properties of nitrous gas, and in particular its rapid combination with pure air, indicate its analogy with combuſtible bodies; and Macquer has remarked, that the artificial fixation of the nitrous acid, which takes place in the mixture of theſe two gaſes, is a kind of combuſtion. But as this appearance is not accompanied with flame, I have not judged it proper to rank the nitrous gas among the inflammable gaſes.

V. The aerated muriatic gas, or dephlogiſticated muriatic gas of Scheele, is obtained with great facility during the mutual action of the native calx of manganeſe, and the muriatic acid: it is known that this production of a peculiar gas is due to the tranſition of the baſe of pure air, or the oxyginous principle of the calx of manganeſe into the muriatic acid. This gas always has a yellow greeniſh colour, with a ſtrong and penetrating ſmell; it is not acid, extinguiſhes flame, and quickly deſtroys animal life; diſcolours dyed ſtuffs, the tincture of turnſole, ſyrup of violets, and vegetables, by reducing them to a white. It diſcolours, and even blanches yellow wax, &c. It decompoſes the volatile alkali, which may therefore be uſed as a preſervative againſt its noxious effects; it ſeparates the mephitis, in proportion as the oxyginous principle of the muriatic gas unites with the inflammable gas of the volatile alkali, with which it forms water. It thickens fat oils, calcines metals, not excepting mercury and gold, and diſſolves in water, to which it communicates all theſe properties. The contact of light gradually decompoſes it, and reduces it to the ſtate of pure muriatic acid.

The formation of the aerated muriatic acid, and its gas, is one of the moſt ſingular diſcoveries of modern chemiſtry; this diſcovery ſhews that the habitude of the muriatic acid with combuſtible bodies is abſolutely contrary to that of the other acids: all theſe ſalts appear, in fact, to be decompoſed by many metals, which have in general a ſtronger attraction for the oxyginous principle, than exiſts between this laſt and the combuſtible baſes of the acids. The muriatic acid, on the contrary, is not decompoſed by metals, which cannot deprive it of its oxyginous principle; and in conſequence of this property, it does not appear to act on the greater part of them; its baſe, nearly diſcovered, not only attracts the acidifying principle with great force, but is even capable of taking it from many metallic calces, as has been inſtanced in the calx of mangancſe. An exceſs of the oxyginous principle takes away its acidity, which is contrary to what happens with many other combuſtible bodies.* This exceſs renders it capable of acting on ſuch metals, as in its ordinary ſtate it does not affect; ſuch in particular are the regulus of antimony, mercury, ſilver, and gold. In proportion as theſe metals deprive it of the exceſs of the oxyginous principle, they become calcined, and are diſſolved in the muriatic acid, which recovers, at the ſame time, its firſt ſtate. Theſe calcinations and metallic ſolutions, by the aerated muriatic acid, are made without efferveſcence, like the ſolution of a ſalt in water; becauſe the metal gradually takes away the ſuperabundant oxyginous principle from the liquid, without being neceſſitated to diſengage the combuſtible baſe. Theſe properties of the muriatic acid, and more eſpecially the reduction of the metallic calces, ſeem to point out that it contains ſome principle of an oily nature.

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* It muſt be remarked in this place, that the name of oxyginous principle does not ſeem in all caſes to agree with the baſe of air, ſince its combination does not always form acids; and ſince it even deprives the muriatic acid of its acidity. T.

VI. The cretaceous acid gas, originally called fixed air by Dr. Black, who firſt diſcovered it in chalk and alkali, requires the moſt attentive conſideration. We ſhall confine ourſelves at preſent to the enumeration of the effect which the diſcovery of the properties of this elaſtic fluid has had on the whole of chemical ſcience. Firſt, it has added one to the number of acids. Secondly, it has ſhewn the cauſe of the effervеſcence which mild alkalies, chalk, calcareous ſpar, and magneſia, produce with ſtronger acids than itſelf. Thirdly, it has cauſed a diſtinction to be made of all alkaline matters into two ſtates, the ſtate of purity or cauſticity, and the mild ſtate, having the property of effervеſcence. Fourthly, it has greatly enlightened the hiſtory of the elective attractions of acids for volatile alkali and lime. Fifthly, it exhibits the firſt inſtance of an acid, which prefers lime to fixed alkalies. Sixthly, the hiſtory of mephitic caverns, in which animals cannot live, is become very clear and ſimple, in conſequence of this diſcovery. Seventhly, the analyſis of waters has been rendered more perfect from the accurate knowledge of ſuch as are called gaſeous, ſpiritous, acidulous, and in conſequence of that knowledge we have ſucceeded in perfectly imitating them. Eighthly, it has thrown great light on the ſolution of iron in many waters, and on the means of procuring martial waters entirely ſimilar to thoſe in nature. Ninthly, It has exhibited a claſs of neutral, earthy, alkaline, and metallic ſalts, in which the cretaceous acid is a principal part; and which are diſtinguiſhed in this work by the name of chalks. Laſtly, it has opened a new field to the reſearches of chemiſts and natural philoſophers, and has given new ardour to thoſe who made theſe diſcoveries. The name of Black will be ever memorable in the annals of chemiſtry, and will endure as long as the ſcience itſelf.

The formation of the cretaceous acid by the union of charcoal and the baſe of pure air, as aſſerted by Mr. Lavoiſier, is at preſent admitted by many French chemiſts. This theory explains all the phenomena relative to the production of this elaſtic fluid, ſince it is known that plumbago conſiſts of charcoal united to a ſmall portion of iron. That ſome metals, particularly iron, contain in many caſes plumbago already formed.*

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* Meſſrs. Vandermonde, Monge, and Berthollet, have made a ſeries of experiments concerning the principal ſtates in which iron exiſts, and have determined that their difference depends on the quantity of plumbago, and of the oxyginous principle they contain. They conſider, 1. caſt iron as iron, a part of which ſtill retains the oxyginous principle, and is combined with various doſes of plumbago. 2. Forged iron as the pureſt of all, or the neareſt to the perfect metallic ſtate, containing the ſmalleſt poſſible quantity of plumbago;

As to the production of this acid by the electric ſpark in vital air, it muſt be obſerved, that in the experiments of Mr. Landriani, the iron, which ſerved as a conductor to the electric fluid, is the cauſe of this phenomenon by virtue of the plumbago it contained, and the ſmall quantity of acid produced is an additional proof that this explication is well founded. There are, doubtleſs, many caſes, in which the cretaceous acid is decompoſed and reſolved into its principles like the other acids. Thus it is, for example, that water, charged with this acid, is much better adapted for the production of vital air by means of leaves expoſed to the rays of the ſun; becauſe the vegetable organization abſorbs the carbonaceous principle, while the light, acting like heat, contributes to the ſeparation of the oxyginous principle in the form of vital air. It is ſtill more remarkable, that certain calces of iron, diſtilled in the pneumatic apparatus, afford only the cretaceous acid in paſſing to the ſtate of Æthiops or black calx of iron. This

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plumbago; from which, however, this metal is never totally deprived. 3. Steel as a compound of iron, perfectly reduced with more or leſs plumbago. Note of the author.

The author ought not to have omitted mentioning Bergman, by whoſe experiments, given in his invaluable Treatiſe de Analyſi ferri, the foregoing facts were originally aſcertained; more eſpecially as the ingenious chemiſts here cited do not appear either from neceſſity or inclination diſpoſed to conceal the claims of that great philoſopher. T.

depends on the coal or the plumbago which many ſpecies of iron contain. This principle takes up a portion of the oxyginous principle, and both form the cretaceous acid.

VII. The ſulphureous acid gas, named vitriolic acid air, by Dr. Prieſtley, is formed whenever a combuſtible body takes away a part of the oxyginous principle, which is united to ſulphur in the vitriolic acid. It ſeems, therefore, to be nothing but ſulphur united to a quantity of the oxyginous principle leſs than that with which it conſtitutes vitriolic acid; it is a kind of middle ſubſtance between this laſt and ſulphur; it is likewiſe formed when ſulphur burning ſlowly abſorbs but a ſmall quantity of the baſe of the pure air contained in the atmoſphere.

The ſulphureous gas is very ſoluble in water; it deſtroys many vegetable colours; and in this character it reſembles the aerated muriatic acid. So that its oxyginous principle ſeems to be either totally or nearly diſengaged. When united with alkaline baſes, the ſulphureous acid gas forms neutral ſalts different from thoſe which are formed by the vitriolic acid, both in their figure, their taſte, and more eſpecially in the property of being decompoſed by the more feeble acids, not excepting even that of vinegar. The ſulphureous neutral ſalts gradually abſorb the oxyginous principle of the atmoſphere, and do not then differ from ſalts formed by the vitriolic acid itſelf.

As the metals which reduce the vitriolic acid into the ſtate of ſulphureous acid gas do not effect this, but by the aſſiſtance of a certain degree of heat, it appears that this decompoſition is the conſequence of a double attraction. In fact, while the metal tends to abſorb the oxyginous principle of the vitriolic acid, and becomes calcined, the heat combines with the ſulphur and a portion of the oxyginous principle, and thus produces the ſulphureous gas. But this gas is one of thoſe which has been fixed or condenſed into the liquid ſtate by mere refrigeration; and from this circumſtance we may form a general concluſion reſpecting the permanency of the elaſticity of theſe fluids.

VIII. The fluor, or ſparry acid gas of Dr. Prieſtley, is obtained from fluor or vitreous ſpar by means of the vitriolic acid. The characteriſtic property of the ſparry acid, is to diſſolve and volatilize in its elaſtic ſtate, the quartzoſe earth which it ſeizes from glaſs veſſels. With alkaline baſes it forms ſalts, totally different from thoſe of the other acids; and it has not yet been determined that it is a modification either of the vitriolic, or of the muriatic acids; though ſeveral chemiſts have maintained this opinion. Its principles are not known, more particularly its baſe; but the preſence of the oxyginous principle is admitted in this as well as in all the other acids.

IX. The muriatic acid gas of Dr. Prieſtley is eaſily obtained, by heating ſpirit of ſalt, or liquid muriatic acid in a retort, whoſe neck is plunged beneath a veſſel filled with mercury. It may likewiſe be obtained in the ſame apparatus, by heating a mixture of common ſalt and oil of vitriol. This elaſtic fluid has a ſtrong and penetrating ſmell. It extinguiſhes candles, deſtroys the life of animals, reddens blue vegetable colours, abſorbs the vapours of water which float in the air, and forms with them a white fume. In liquid water it becomes diſſolved, and loſes that heat which maintained its elaſtic ſtate. It cauſes ice to melt with great rapidity, by reaſon of the heat it gives out the inſtant of its combination with water. It is abſorbed by charcoal and by ſpunge; unites with all the alkaline baſes, and forms muriatic ſalts; and diſſolves camphor. The nature of this air is not yet well known; neither has any one yet ſucceeded in ſeparating the oxyginous principle from its baſe. It does not act on metals, which conſequently are incapable of decompoſing it, as they do the other acids. Theſe properties ſhew, that the liquid muriatic acid, or ſpirit of ſalt, is nothing more than an acid fixed in the water, of whoſe liquidity it participates. It has not yet been accurately determined at what degree of heat and preſſure it acquires, and preſerves the ſtate of elaſtic fluidity. Theſe facts, together with thoſe which conſtitute the hiſtory of the aerated muriatic gas, tend greatly to explain the ſolution of metals by this acid, and its ſmall degree of action on oils, ſpirit of wine, &c.

X. The alkaline gas, diſcovered by Dr. Prieſtley, is diſengaged by heat from the volatile fluor alkali, and ſtill more readily from the mixture of common ſal-ammoniac with quick lime. This fluid collected in glaſs veſſels over mercury, is ſomewhat heavier than atmoſpheric air; it has not been determined at what degree of cold or preſſure it loſes its aeriform fluidity. It unites with water, giving out at the ſame time much heat. It melts ice, converts the ſyrop of violets, and blue and red flowers to a green; and combines rapidly with the acid gaſes of chalk, ſulphur, and common ſalt. Theſe combinations are attended with much heat, which immediately abandons the two elaſtic fluids at the inſtant that they become ſolid.

Alkaline gas is rapidly decompoſed by the contact of aerated muriatic gas, the decompoſition being attended with heat. Water charged with the muriatic acid is formed, and the aeriform mephitis remains. This experiment, as well as many others already cited, ſhews, that the volatile alkali is compoſed of inflammable gas and mephitis. The decompoſition of ammoniacal copper of fulminating gold, which produce water by means of the action of fire; the reduction of the metal, and the mephitis obtained, ſtill further prove that the volatile alkali is compoſed of the principles here mentioned. In fact, the inflammable gas contained in the alkali, having more affinity with the oxyginous principle than the copper and the gold have, takes it from the calces of theſe metals, and forms water, leaving, at the ſame time, the mephitis in a ſtate of liberty. The calces of zink and of iron, which decompoſe water in their metallic ſtate, do not decompoſe the volatile alkali in the ſame manner; becauſe theſe metals have a greater affinity with the oxyginous principle than the latter has with the inflammable gas.

XI. Pure, or aqueous inflammable gas, univerſally known by the improper name of inflammable air, is the lighteſt of all the aeriform fluids. When it is very pure, it is thirteen times lighter than atmoſpheric air; extinguiſhes fire; kills animals; takes fire* by the contact of the electric ſpark, or any combuſtible body already in a ſtate of ignition; and burns with a brilliant flame. Fourteen parts of this gas in weight abſorb eighty-ſix of vital air, during their complete combuſtion; and very pure water is formed, provided theſe two fluids themſelves be in a ſtate of purity. All ſubſtances, which have a greater affinity with one of theſe two principles of water than they have with each other, decompoſe this liquid. Thus it is, that iron, zink, charcoal, and oils, decompoſe water, and ſeparate the inflammable gas, becauſe theſe bodies have more affinity with the baſe of the vital air, or the oxyginous principle, than this laſt has with the inflammable gas. Hence it is clear, that the inflammable gas cannot decompoſe the cretaceous acid, and the calces of zink and of iron. On the contrary, ſulphur, and the metals which do not decompoſe water, give out the oxyginous principle they contain when in the ſtate of vitriolic acid, or of metallic calces, to the inflammable air; by which means the firſt is reduced to the ſtate of ſulphur, and the ſecond to the metallic ſtate. It is this decompoſition of water by iron and zink, which is the cauſe of the inflammable gas produced during the ſolution of theſe two metals in the vitriolic, muriatic, cretaceous, and acetous acids.

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* Provided vital air be preſent. T.

The leaves of vegetables, on the contrary, poſſeſs the property of abſorbing the inflammable gas of water, and permitting the oxyginous principle to become diſengaged in the ſtate of pure air. Light contributes much to this decompoſition, which does not take place without its contact; it ſeems to melt, or give fluidity to the oxyginous principle, and cauſes it to become pure air. In proportion as this air is diſengaged, the inflammable gas becomes fixed in the plant, and doubtleſs cauſes the production of oil. It is not yet known what ſubſtances inflammable air combines with in order to form oils.

Inflammable gas combined with mephitis, conſtitutes the volatile alkali, as we have already obſerved. This compoſition has been analytically demonſtrated by Mr. Berthollet, but he has not yet ſucceeded in compoſing the volatile alkali by the direct union of theſe two bodies.

The matter of heat contained in inflammable gas has not yet been ſeparated, except in ſuch caſes as this body enters into a compound ſtate; the baſe of this aeriform fluid is therefore unknown. The preſſure and the degree of cold neceſſary to effect this ſeparation are not yet in our power; and every experiment ſerves to ſhew that both the one and the other muſt be in the extreme to produce this effect.

It is to the ſudden diſengagement and rapid inflammation of this gas, that all the fulminations and detonations obſerved in chemiſtry are to be attributed, and the inſtantaneous recompoſition of water is very often the reſult of theſe detonations.

Inflammable gas is greatly concerned in the phenomena of nature. It is produced and diſengaged in large quantities in mines. It reduces and colours many metallic calces. When elevated in the atmoſphere, it is tranſported by the winds, and ſet on fire by electricity, where it conſequently conſtitutes a part of the lightning; and in its detonation immediately forms water, which falls on the earth.

The inflammation of this gas by the electric ſpark is one of thoſe moſt curious phenomena, whoſe cauſe is the leaſt underſtood. The ſame difficulty occurs, when we conſider the power of the electric ſpark to fix the mixture of pure air and mephitis in the form of nitrous acid.

XII. Hepatic gas has been well diſtinguiſhed from the other inflammable gaſes by Bergman. It is obtained from livers of ſulphur, or ſolid hepars, decompoſed by means of acids in the pneumatic apparatus. This aeriform fluid has a very fetid odour. It kills animals, and turns the ſyrup of violets green. Vital air precipitates the ſulphur. It takes fire by the electric ſpark, and by the contact of inflamed bodies, burning with a reddiſh blue flame, ſulphur being at the ſame time depoſited on the ſides of the veſſels. The ſmoking nitrous acid, and the ſulphureous acid decompoſe, or deſtroy its elaſtic fluidity, and ſeparate the ſulphur. This gas unites with water; but the ſolution is decompoſed by expoſure to the air, and by the ſame acids as decompoſe the gas itſelf. Hepatic gas gives a deeper colour to the calces of lead and biſmuth, and even reduces them. It precipitates muriatic ſolutions. Some metals, and in particular mercury and ſilver, ſeparate the ſulphur, ſo that it cannot be transferred in veſſels over mercury without a great part of it being decompoſed.

All theſe phenomena ſhew, that this gas contains ſulphur in a ſtate of extreme diviſion. Mr. Gengembre, who has analyzed it, thinks it conſiſts of pure or aqueous inflammable gas and ſulphur. It is the diſſolution or ſuſpenſion of this laſt, that gives it its diſtinctive characters. The ſulphur, notwithſtanding its ſtate of extreme diviſion, does not burn at the ſame time as the inflammable gas, but is depoſited in part during the combuſtion of the latter.

It is this gas which mineralizes the ſulphureous or hepatic waters. The ordinary acids do not precipitate the ſulphur; but the fuming nitrous acid, and the ſulphureous acid, in which the oxyginous principle is not ſtrongly adherent, ſeparate the ſulphur, while they abſorb the inflammable air.

The knowledge of hepatic gas explains many difficulties relating to the nature of ſulphur. Firſt, we know why the ſolid hepar has ſcarcely any ſmell, and why it emits ſo ſtrong a ſmell when it is moiſtened.

Secondly,

Secondly, it appears that water, which ſulphur alone is incapable of decompoſing, is eaſily ſeparated into its principles, by the double action of ſulphur and alkaline matters. Thirdly, the decompoſition of livers of ſulphur by expoſure to air, and by many metallic calces, which are incapable of decompoſing water, is eaſily underſtood. Fourthly, the theory of the formation of ſulphureous mineral waters may be readily explained, as well as the hiſtory of their decompoſition.

XIII. Phoſphoric gas was diſcovered by Mr. Gengembre; he obtained it by boiling a ſolution of cauſtic vegetable alkali with half its weight of phoſphorus, and receiving the elaſtic fluid, which is diſengaged under glaſs veſſels filled with mercury. This gas is very fetid, deſtroys animal life, takes fire ſpontaneouſly by the contact of air; and with a ſlight exploſion. The ſolid phoſphoric acid, which it affords by burning, forms a kind of crown in a ſtill air, which increaſes in diameter as it riſes. When vital air is mixed with this air under glaſs veſſels, it burns with great rapidity, producing ſo conſiderable a quantity of heat, and conſequently dilatation, that the glaſſes are ſhattered to pieces, unleſs they be very thick. Mr. Gengembre conſiders this new gas as a ſolution of phoſphorus in inflammable gas; it greatly reſembles hepatic gas, from which it differs only in the nature of the combuſtible body ſuſpended in the inflammable gas. As phoſphorus is much more combuſtible than ſulphur, the phoſphoric gas takes fire in the air. The phoſphorus, when inflamed, communicates its combuſtion to the inflammable gas. In the hepatic gas, on the contrary, the inflammable gas does not take fire, but by the contact of ſome body in ignition; and the ſulphur, for want of a ſufficient heat, ſeparates without burning.

XIV. I give the name of mephitized inflammable gas to the aeriform fluid which conſiſts of aqueous, or pure inflammable gas, and mephitis. This gas is the ſame as that which was called inflammable air of marſhes, by Mr. Volta. It is produced by the putrefaction of certain vegetable matters, and of almoſt all animal ſubſtances. It is diſengaged from ſtanding waters, and in all places where animal matters putrify in water. It accompanies, precedes, or follows the formation of the volatile alkali, which takes place in putrefaction. I ſuſpect it to be a ſimple mixture without the chemical compoſition; becauſe volatile alkali would be formed, if the combination were perfect. It differs from volatile alkali, firſt, in the elaſtic ſtate of the two fluids, which conſtitute it; ſecondly, in the proportion of theſe elaſtic fluids, which varies in this mixed gas, while the quantity of the combined baſes is always the ſame in volatile alkali. It is to Mr. Berthollet that we are indebted for the exact knowledge we poſſeſs of the properties of this gas. In the years 1778 and 1779, I examined the inflammable gas of marſhes, and obſerved that it contained the cretaceous acid; but in many of theſe gaſes, collected in different places near Paris, I found a mixture, which I did not accurately diſtinguiſh; though I obſerved in my collection of Memoirs, in octavo, page 164, that it is ſometimes accompanied, and even ſucceeded, by the phlogiſticated gas; which, as I have elſewhere obſerved, is now called mephitis. Mr. Berthollet has given to theſe aſſertions, which were unſettled at the time that I inſerted them in my Memoirs, a degree of certainty and preciſion, which has induced me to diſtinguiſh theſe gaſes by the name here made uſe of.

Mephitized gas burns with a blue flame; it does not detonate with vital air, without difficulty. After detonation in the eudiometer of Mr. Volta, ſome drops of water are found, and a reſidue of mephitis more or leſs pure.

XV. I diſtinguiſh by the epithet of cretaceous inflammable gas, the mixture of pure inflammable gas and elaſtic cretaceous acid.

It is obtained by diſtillation, from many vegetable matters, and in particular from tartar, and all the tartareous ſalts, or the acetous ſalts; from hard woods, or charcoal which is burned by the aſſiſtance of water, from pit coal, &c. It burns with difficulty; but the cretaceous acid may compoſe three-fourths of its volume without its ceaſing to be combuſtible. This acid may be ſeparated by means of lime-water, or cauſtic alkalis. It is a ſimple mixture, without combination. The inflammable air cannot, in fact, decompoſe the cretaceous acid, becauſe the carbonaceous principle, or charcoal, decompoſes the water, with whoſe oxyginous principle it has a greater affinity than this laſt has to the inflammable gas.

XVI. Laſtly, it is now known, that charcoal, though very fixed in cloſed veſſels, and in our ordinary fires, is capable of being reduced into vapours, by means of a very high temperature; and that it is likewiſe ſoluble in elaſtic fluids. Inflammable gas, more eſpecially, has the property of diſſolving this ſubſtance, and of holding it ſuſpended; it is often, therefore, taken up by this fluid, at the time of its aſſuming the elaſtic form. It is this fixed gas which is diſengaged, when caſt iron or ſteel is diſſolved in ſpirit of vitriol; the carbonaceous matter being abſorbed by the firſt in the furnace, and by the ſecond during the cementation. It is even found that charcoal may be immediately diſſolved in this gas, by cauſing the united rays of the ſun, by means of a mirror, to fall on a piece of that ſubſtance placed above the mercury, made uſe of to confine the inflammable air. This fluid burns with a blue flame, attended with ſmall white or reddiſh ſparkles. The charcoal diſſolved in this gas modifies its effects, and alters the reſults of its combinations. Hence it is, that a mixed gas, formed by the ſolution of charcoal in mephitis, appears to be the colouring matter of Pruſſian blue, as Mr. Berthollet conjectures. We are not yet acquainted with all the compounds into which charcoal enters; and the ſame obſervation is likewiſe applicable to the various mixtures of all the gaſes with each other, which certainly take place in many combinations and decompoſitions, and have not yet been ſtrictly attended to by chemiſts.

§ IV. The Application of ſuch Facts, as are known reſpecting the Nature and Properties of elaſtic Fluids, to the great chemical Phenomena of Nature and Art.

It is now well known, that there is ſcarcely a ſingle chemical phenomenon, in which a diſengagement or fixation of ſome elaſtic fluid does not take place; and that both theſe events frequently happen at the ſame time. The diſcoveries of the modern chemiſts ſhew, therefore, that the ancient explications of theſe phenomena were not ſatisfactory; and the many difficulties, which theſe diſcoveries have removed, ſufficiently ſhew their importance in the ſcience of natural philoſophy.

When we compare the numerous facts, which form the whole of our knowledge of chemiſtry together, we find that they may be reduced to certain general claſſes.

This arrangement is become ſo much the more neceſſary, as the connection and mutual illuſtration of theſe facts muſt hereafter conſtitute the true elements of chemical ſcience; but this laſt object cannot be properly accompliſhed till all the general phenomena are explained; and as many of them yet remain in obſcurity, this elementary method of treating the whole of chemiſtry, cannot, in the preſent ſtate of our knowledge, be conſidered otherwiſe than as a project or ſcheme, whoſe importance and utility deſerve the ſerious attention of natural philoſophers. It is by way of aſſiſting in the execution of this project; or at leaſt with a hope of ſhewing the poſſibility of its execution, that I have thought proper to collect all the facts and chemical theory under ſixteen principal heads, which comprehend the various changes produced in natural bodies by means of their chemical attraction. And that theſe phenomena may be explained methodically,

thodically, by proceeding from ſimple effects to thoſe that are more compound, I ſhall diſpoſe them in the following manner:

1. The production, or diſengagement of heat and its abſorption, with the effects of the one and of the other.
2. The effects of air in combuſtion.
3. The effects of light upon bodies.
4. The formation of water, and its decompoſition.
5. The production and decompoſition of earths.
6. The formation and decompoſition of alkalis.
7. The formation and decompoſition of acids.
8. The combination of acids with earths and alkalies.
9. The peculiar combuſtion of diamond, of inflammable gas, of ſulphur, and of plumbago.
10. The calcination and reduction of metals.
11. The diſſolution of metals by ſalts, and the properties of neutral metallic ſalts.
12. The formation of the immediate principles of vegetables by vegetation.
13. The production, the differences, and the decompoſition of vegetable acids.
14. The ſpirituous fermentation; the com-

combuſtion, and combinations of ardent ſpirit.

15. The formation of animal matters.

16. The decompoſition of animal matters and putrefaction.

We will briefly conſider each of theſe phenomena, and ſhew their connection with the properties of elaſtic fluids.

I. The production of heat ariſes either from a ſtrong preſſure, which diſengages it from bodies in which it was included, or from a combination by which it is ſet at liberty. It muſt be obſerved, that this phenomenon takes place more eſpecially when an elaſtic fluid becomes fixed in a body; becauſe the aeriform ſtate ſuppoſes, as we have already explained, the preſence of a great quantity of combined heat. It muſt likewiſe be obſerved, that various bodies containing different quantities, or having different capacities for heat; preſſure, or combination, cauſes it to be extricated in very different doſes. This phenomenon, therefore, which accompanies a great number of chemical operations, requires to be attended to and eſtimated with great exactneſs in all experimental inquiries.

The ſame obſervation holds with reſpect to the apparent deſtruction or abſorption of heat, very frequently obſerved in chemical proceſſes. It always depends on the augmentation of the magnitudes of bodies, by means of which their capacities for the matter of heat are increaſed. We may, therefore, conceive mechanically, or by the ſimple conſideration of the change that takes place among the particles of bodies, what happens in both the phenomena.

II. Combuſtion is one of the moſt important phenomena in nature. There are two kinds or claſſes of combuſtion; namely, ſuch as are made with acceſs of common air, and ſuch as apparently are made without the acceſs of air; though, in fact, it is contained in the ſubſtances themſelves.

Combuſtions effected by the contact of air, are, as we have already obſerved, combinations of the combuſtible body with the baſe of vital air, or the oxyginous principle. In proportion as theſe combinations take place, the matter of fire is ſeparated from the oxyginous principle, and appears under the form of heat and light. There are combuſtible bodies which ſlowly diſengage the fire of the air, and do not give out heat ſufficiently ſtrong to deſerve the name of combuſtion. Others, on the contrary, cauſe the fire to be diſengaged rapidly, under the form of light; and at the ſame time giving a greater or leſs degree of oſcillation to this light, they cauſe different ſhades of colour, if the theory of Euler reſpecting the luminous rays of different colours be admitted, which aſſerts, that they conſiſt of the ſame matter vibrating differently. In certain combinations, effected in the open air, the combuſtible bodies have ſo ſtrong a degree of attraction to the baſe of this elaſtic fluid, that they very readily ſeize it. Others, in order that they may combine with the oxyginous principle, require a very high temperature, which ſeems to favour the attraction of combuſtible bodies for this baſe. This theory explains how bodies become heavier by being burned, and the cauſe of impurity of the atmoſpheric air after combuſtion; for the proportion of mephitis then becomes much greater. And the diverſity of phenomena, ſuch as flame, heat, and rarefaction, which accompany every kind of combuſtion made in the air, are by this theory explained with equal facility.

The ſecond kind of combuſtion is very often performed in cloſed veſſels. It conſiſts, in general, in the tranſition of the oxyginous principle from a body already burned, into another which has not been burned. It depends on the different elective attractions of the oxyginous principle for the ſeveral combuſtible baſes. Such is the calcination of metals by acids; the reduction of metallic calces by charcoal; the combuſtion of ſulphur, of phoſphorus, of charcoal, and of plumbago, by the nitrous acid; the combuſtion of the baſes of inflammable gas fixed as a principle in ſal-ammoniac or volatile alkali, by the muriatic or aerated acid, &c. &c. In all theſe caſes, the oxyginous principle paſſes from one body into another; and as it does not appear to be melted into an elaſtic fluid by the fire, theſe combuſtions are very often made without the appearance of flame. We may likewiſe add, that in theſe ſlow combuſtions, the combuſtible property is not loſt, but is renewed in the body, which parts with its oxyginous principle, while it ceaſes to exiſt in the other body which has abſorbed it.

III. The effects of light on bodies have not yet been eſtimated but by their reſults; the cauſe not having yet been well explained. The action of light upon vegetables has long been known; namely, that it colours them, and produces combuſtible bodies. Scheele obſerved, that the rays of the ſun colours the nitrous acid, luna cornea, mercurial precipitates, &c.; and it is now acknowledged that all theſe effects are accompanied with the diſengagement of a certain quantity of vital air. Light, therefore, acts in the ſame manner on theſe bodies as heat. It ſeparates the oxyginous principle, which it melts, and cauſes to paſs to the ſtate of elaſtic fluidity. In this manner it is, that it contributes to the decompoſition of the cretaceous acid by means of the leaves of vegetables, by a double affinity; firſt, that of light, with the oxyginous principle, which is diſengaged in the form of vital air; and ſecondly, that of the vegetable matter, with the carbonaceous principle. It is by the ſame action, that light favours the decompoſition of water by means of the organs of vegetables, and contributes to the formation of the oxyginous principle. By attending more carefully to the action of light on many natural bodies than has yet been done, there is no doubt but important diſcoveries will be made, as I obſerved in the year 1780.

IV. The formation of water, and its decompoſition, depend entirely on the affinities of the oxyginous principle, which is one of its component parts. It has been for ſome time known, that zink, iron, oils, and charcoal, have the property of ſeparating the component parts of water from each other, by abſorbing the oxyginous principle, and diſengaging the inflammable gas. The extreme tenuity or lightneſs of this gas is the cauſe why ſo high a temperature is neceſſary for immediately effecting of this decompoſition. It ſeems that the baſe of this gas, which is uſually either liquid or ſolid, in the two moſt common ſtates of water at the ſurface of the globe, has a very great capacity for the matter of heat; and it even ſeems that this baſe, though combined with the oxyginous principle in the form of water, ſtill poſſeſſes the property of abſorbing much of that matter. It is by virtue of this property, that aqueous vapour is lighter than air. This happy diſcovery

covery of the nature of water, and its decompoſition, throws great light on the theories of metallic ſolutions, of the calcination of many metals by the vapour of water, the formation of the immediate principles of vegetables, of ardent ſpirit, and the putrefactive fermentation. And it may alſo be obſerved, that the theory of almoſt every fact in chemiſtry depends on the affinities of the oxyginous principle. Hence, likewiſe, we are enabled to explain ſeveral of the atmoſpheric phenomena, as well as others relating to the formation of metals, and the laws followed by nature in the ſucceſſive changes of organic matters, &c.

V. There are many important ſubjects of inquiry reſpecting of natural bodies, which are ſtill deſiderata among chemiſts. The formation of earths is one of theſe. Naturaliſts have entertained various opinions reſpecting the nature of earths. Many have thought that the transformation of ſilex into clay, was well proved; but theſe notions deſerve to be conſidered in no other light than as ingenious hypotheſes not yet proved by the facts. No chemiſt has yet converted ſiliceous earth into clay, nor clay into ſiliceous earth. Nature may, perhaps, produce this converſion; but art, which is not yet in poſſeſſion of the means, can do nothing, till direct experiments have pointed them out. In the ſame manner ponderous earth, magneſia, and lime, have been conſidered as compounds of the preceding earths, with certain other bodies; but theſe are ſuppoſitions not at all to be depended on. No chemiſt has yet directed his reſearches to this point, and the firſt data are ſtill wanting.

VI. The formation of fixed alkalis is in the ſame ſtate of uncertainty; and though ſuch chemiſts as are well acquainted with modern diſcoveries, may perhaps ſuſpect that the mephitis is a principle of theſe ſalts; it may even perhaps be admitted, that the baſe of this elaſtic fluid, which has been proved by Mr. Berthollet to exiſt in the volatile alkali, is the general principle of fixed alkalis, and alkaline earths; or in a word, the alkaliginous principle. It cannot, for example, be doubted but that fixed alkalis are partly decompoſed in many chemical operations; they are manifeſtly changed into volatile alkali in the diſtillation of old ſoaps, and of the tartareous and acetous neutral ſalts. This converſion ſeems to ſhew, that fixed alkalis contain mephitis, which acting on the inflammable gas of the oil, forms volatile alkali. But the facts have not yet been examined with ſufficient care, as to the quantities of the fixed alkali which appear to be decompoſed, the volatile alkali they afford, and eſpecially with regard to the reſidue, to admit of any ſtrong dependence on this theory, though it muſt be allowed to poſſeſs no inconſiderable degree of probability.

VII. The formation of acids, and their decompoſition, is one of the beſt known and moſt uſeful of the reſults of modern chemiſtry. It is known, that they are all formed of a baſe more or leſs combuſtible, united to the baſe of air; that this laſt being the ſame in all, is the cauſe of their acidity, and that their differences depend only on the ſubſtance combined with the oxyginous principle. It is known that the baſes of the vitriolic, nitrous, cretaceous, arſenical, and phoſphoric acids, are the ſubſtances called ſulphur, mephitis, charcoal, arſenic, and phoſphorus; but the baſes of the muriatic, ſparry, and boracic acids in the mineral kingdom, and moſt of thoſe belonging to the vegetable kingdom, are ſtill undiſcovered.

This decompoſition of acids is not difficult either to be conceived or explained. It takes place whenever a combuſtible body is preſented to the acid, which has a ſtronger affinity with the baſe of air than this laſt has with the other principle of the acid: on this depends the theory of the formation of ſulphureous and nitrous gaſes, &c.

VIII. The combination of acids with earths and alkalis conſtitutes the hiſtory of neutral ſalts, and of the affinities, or the elective attractions of theſe different matters for each other. It comprehends the examination of ſuch phenomena as take place during their union; the taſte they acquire, their form, ſolution, and cryſtallization; their alterations by fire, by air, and the mutual decompoſitions they undergo. This ſubject is treated of at large in the following work.

IX. The peculiar combuſtion of diamond is well known, as far as relates to the facts; but the compound produced by this combuſtion has not been examined. As to the combuſtion of the inflammable gas of ſulphur, and of plumbago, it is referable to the hiſtory of water, and of the vitriolic and cretaceous acids. The carbonaceous inflammable air afforded by iron, zink, and perhaps many other metals during their ſolution in the vitriolic, muriatic, and acetous acids, and the cretaceous acid obtained by the detonation of the ſame matters with nitre, may be attributed to the plumbago contained in thoſe metals.

X. The calcination and reduction of metals likewiſe conſtitute a part of the hiſtory of air and the oxyginous principle. The calcination of metals is now known to be a kind of combuſtion, conſiſting in the union and fixation of the baſe of air. Metallic calces being compounds of metals, and the oxyginous principle, the greater part of them cannot be reduced, but by the application of a body which has a ſtronger affinity with the latter, than this has with metallic ſubſtances. Charcoal, in this manner, abſorbing the oxyginous principle of metallic calces, forms with it the cretaceous or carbonaceous acid, which is diſengaged in great quantities during their reduction. Certain metallic calces give out the oxyginous principle in the form of vital air, by the mere aſſiſtance of heat. Theſe facts prove, that the oxyginous principle adheres to different metallic matters with various degrees of force; but two very important circumſtances relative to the calcination of metals, and determined by the experiments of modern philoſophers, are, firſt, that each metal abſorbs a different quantity of the oxyginous principle, in order to its ſaturation. 2. That each of them may exiſt in very different ſtates of calcination, or combined with different doſes of the oxyginous principle, from the very commencement of calcination to its being perfectly finiſhed.

An attentive examination of this ſecond fact leads us to diſtinguiſh in each metallic calx ſeveral different ſtates depending on the quantity of the oxyginous principle it contains. Thus we ſee that mercury, ſlightly calcined, is changed into a black powder in a variety of circumſtances, which has been ſuppoſed to be the metal in a ſtate of extreme diviſion. In like manner, iron, in the form of Æthiops martial, is the firſt of its calces on account of the ſmall quantity of the oxyginous principle it contains. Cold water readily converts iron into this ſtate. Laſtly, copper, which is beginning to be calcined, or is united to the ſmalleſt poſſible quantity of the oxyginous principle, is brown or reddiſh white; while its perfect or ſaturated calx is of a deep green.

This diſtinction of metallic calces into different ſtates of calcination, depending on the various quantities of the oxyginous principle contained in them, ſerves to explain a great number of phenomena, which were formerly attended with much difficulty.

XI. The ſolution of metals in different acids, the properties of theſe ſolutions, and the ſalts they furniſh, agree likewiſe with the modern theory, and admit of a much clearer explanation than formerly. No ſolution can take place in an acid, unleſs the metal be firſt calcined.

Metals are calcined by the vitriolic acid, either by the acid itſelf, or by the water it is combined with. In the firſt caſe the acid is decompoſed, and ſulphureous gas is diſengaged; in the ſecond, the water is decompoſed, and inflammable gas is diſengaged. Some of the metals do not decompoſe the vitriolic acid, unleſs water be preſent; ſuch are mercury, lead, &c. In the firſt caſe, the metals are not burned, unleſs the vitriolic acid be concentrated; in the ſecond caſe, the metal has more power to decompoſe water, than to decompoſe the vitriolic acid. Zink, iron, and other metals do not, therefore, readily become calcined, but by means of the diluted acid, becauſe it is in fact the water which calcines them. The proof of this laſt fact is, that the vitriolic acid remains entire without decompoſition. It is clear after this explanation, that a much greater quantity of the vitriolic acid will be required to diſſolve a metal which decompóſes the acid itſelf, than would be required to diſſolve another metal, which decompoſes water united to this acid: becauſe in the former caſe, two different quantities of the acid are required; the firſt to calcine the metal, the ſecond to diſſolve the metallic calx: ſo that if no more were applied to the metal than the firſt mentioned quantity, nothing but a calx would be produced; and the ſecond or additional quantity of vitriolic acid would be required to diſſolve it. This is frequently done in our laboratories. Accurate obſervation has ſhewn, that metallic calces require a determinate proportion of the oxyginous principle, in order that they may be ſoluble in the vitriolic acid. When they are ſaturated with this principle they are not ſoluble, and long before ſaturation they are likewiſe inſoluble. Thus we ſee, that when a vitriolic ſolution is too ſtrongly heated, or has been long expoſed to the air, in the firſt caſe the heat favours the action of the metallic calx on the acid, ſo that it takes a greater quantity of the oxyginous principle than it had before; and conſequently, it does not remain ſuſpended in the acid: or, in the ſecond caſe, it abſorbs this ſame principle from the atmoſphere, and when this exceeds the determinate quantity neceſſary for its remaining ſuſpended, it falls of courſe. Hence the theory of vitriolic mother-waters. The metallic ſolutions in this acid do not afford cryſtals, but in the former caſe; and all theſe facts ſhew, that the metals themſelves at firſt act on their ſolvents, and that the vitriolic acid does not attack them, till they have ſuffered a determinate degree of calcination.

The nitrous acid is likewiſe decompoſed by the greater number of metals. Theſe are calcined to a determinate degree by abſorbing the oxyginous principle, with which they have a greater affinity than with the mephitis; but as they do not deprive the nitrous acid of the whole of its oxyginous principle, at leaſt when the quantities of metal and of heat are not too great, the mephitis is ſeparated, together with a portion of the oxyginous principle; and this peculiar combination forms nitrous gas. The nitrous is the moſt eaſily decompoſed of all the acids. Its two principles adhere very weakly to each other; for which reaſon it has always been regarded as the principal ſolvent. Hence we ſee, likewiſe, why water is never decompoſed during the reciprocal action of metals and the nitrous acid; and why this action is rendered nearly ineffectual by the addition of a great quantity of water. From this reaſon likewiſe it is, that metallic ſolutions, by means of the nitrous acid, never give out more than one ſpecies of elaſtic fluid, namely nitrous gas, mixed ſometimes with a ſmall quantity of mephitis; which happens more eſpecially when the metals made uſe of have a very ſtrong affinity with the oxyginous principle, and abſorb it in great quantities.

Such metals, as are ſoluble in the nitrous acid, cannot remain united with it, unleſs the quantity of the oxyginous principle they are combined with be determinate, and not equal to abſolute ſaturation. Many metals, as for example, biſmuth, antimony, mercury, tin, and iron, are ſeparated from the nitrous acid by mere ſtanding, by heat, or by expoſure to air; in which caſes they continue to abſorb the oxyginous principle of the ſolvent acid, or the ſurrounding atmoſphere. The quantity of the nitrous acid muſt be very conſiderable: firſt, that the metal may be calcined; ſecondly, that the calx may be diſſolved. If the firſt quantity only be added, the metal will remain in the form of calx, as happens with biſmuth, zink, tin, and regulus of antimony.

The muriatic acid does not act on any

metal, but by the aſſiſtance of water; ſo that as there are but few metals which act upon water, there are likewiſe few which are immediately ſoluble in the muriatic acid; and during their ſolution by this acid, inflammable air only is diſengaged. Theſe circumſtances indicate, that the principles of the acid have a ſtronger adheſion to each other than thoſe of every other acid; and I am very much inclined to believe from this, that the unknown baſe of the muriatic acid has the ſtrongeſt poſſible affinity with the oxyginous principle; ſince none of thoſe combuſtible bodies, which take it from the greater part of ſuch bodies as contain it, can deprive this acid of that principle. But it diſſolves metallic calces, when once formed, with great facility; and even takes them from ſeveral other acids. It likewiſe diſſolves them when ſaturated with the oxyginous principle, contrary to what happens with the other acids. Theſe two laſt remarkable properties certainly depend on the tendency which the muriatic acid has to abſorb an exceſs of the oxyginous principle; a tendency, which is well demonſtrated by the formation of the aerated muriatic acid and aqua regia. The action of all the other acids on metals is not yet ſufficiently known, to enable us to ſpeak of them with the ſame preciſion as we have done reſpecting the three foregoing. We ſhall therefore only obſerve, that metals ought not to decompoſe the cretaceous acid, becauſe charcoal, which is one of the principles of this acid, has a ſtronger affinity with the oxyginous principle than this laſt has with metals; as the decompoſition of metallic calces, by means of the carbonaceous principle, ſufficiently proves.

Laſtly, the precipitation of metallic calces, when united to acids, in the form of metals, by other metallic ſubſtances, is equally explicable by the various affinities of the oxyginous principle with theſe ſubſtances. When copper precipitates the calx of ſilver, and iron the calx of copper, in the metallic forms of ſilver and copper, the phenomena depend on the greater attraction of copper than of ſilver to the oxyginous principle, and of iron than of copper.

Inquiries into the formation of the immediate principles of vegetables are yet in their infancy. It has been long ſince obſerved, that plants grow very well in the pureſt water; and that by the aſſiſtance of water and atmoſpheric air, they obtain all their conſtituent principles. Theſe, therefore, are the two materials from which they draw all their nouriſhment; or from which the mucilage, the oil, the coal, the acids, the colouring parts, &c. are produced. Since the time of the diſcoveries relating to gaſes, it has been obſerved, that they grow very quickly in air charged or mixed with the cretaceous acid, as well as in inflammable air. We have already obſerved, that leaves of plants decompoſe water and the cretaceous acid. They abſorb the inflammable gas of the former, and the carbonaceous principle of the latter; diſengaging pure air from the one as well as from the other: they therefore muſt abſorb mephitis. Theſe phenomena being properly attended to, tend greatly to explain the formation of charcoal, and of oil; for it cannot be doubted, but that this laſt principle is formed of inflammable gas fixed by ſome other ſubſtance, as it gives out much water during its combuſtion. But we are not yet acquainted with the formation of the colouring principle, of the various oils, of the ſpiritus rector, the fixed alkali, the glutinous parts, &c. We may, however, venture to foretell, that by making experiments on vegetation, as indicated by the new diſcoveries, we ſhall moſt probably arrive at the nature and conſtitution of all theſe immediate principles.

XII. No one has treated more fully and accurately on the hiſtory of vegetable acids than Mr. de Morveau, in his Dictionary of Chemiſtry, which makes a part of the Encyclopedia. He diſtinguiſhes vegetable acids into two claſſes, viz. ſuch as exiſt ready formed in vegetables, and thoſe of which they contain only the baſe, and which are produced by combining this baſe with the oxyginous principle obtained from different bodies, or exiſting in the vegetable itſelf, by means of the alteration its different principles are made to undergo. He obſerves, however, that this diviſion is not perhaps very exact; becauſe the formation of acids, by means of vegetation, reſembles in ſtrictneſs their formation by art; being effected by the combination of the acidifiable baſes with the oxyginous principle in the internal parts of vegetables. Notwithſtanding the force of this obſervation, the diſtinction propoſed by this chemiſt is very uſeful; for the vegetable baſes, which art converts into acids, ſcarcely ever become ſuch in the proceſſes of vegetation.

The firſt claſs may be divided into two orders, as Mr. de Morveau himſelf remarks. In the firſt may be arranged the vegetable acids ready formed, and in a ſtate of purity, which may be extracted by ſimple preſſure or infuſion; as the acid of citrons, and the acid of galls. The ſecond order may comprehend thoſe which are partly neutralized, and are only to be ſeparated by peculiar chemical operations. Such are the acids of benzoin, of tartar, of ſorrel, and of apples.

The ſecond claſs comprehends three orders of vegetable acids. 1. Thoſe which are produced by the acetous fermentation. 2. Thoſe which are obtained by the action of the nitrous acid; as for example, the ſaccharine acid. 3. Thoſe obtained by diſtillation, and known by the names of empyreumatic acids; ſuch are the acids obtained in this way from wood, from ſugar, from tartar, &c. This diviſion of vegetable acids propoſed by Mr. de Morveau, is more exact than that of Mr. Weigel, which does not include the acids produced by the application of the nitrous acid.

We have examined the greater part of theſe acids in the third part of the preſent work; but the diſcoveries lately made, demand that we ſhould in this place attend again to the general properties of all theſe ſalts, and ſome of them more particularly.

The vegetable acids ready formed, whether they be in a ſtate of purity, or whether they be partly neutralized, are the products of a compoſition, effected by the vegetative powers, of an oily baſe with the oxyginous principle. They only poſſeſs the ſecond rank among the immediate principles of vegetables, ſince the formation of oils has neceſſarily preceded their production. As oils differ among each other, vegetable acids muſt likewiſe have different properties; but they are all volatile, and decompoſeable by fire. Thoſe whoſe baſes exiſt only in vegetables, and are formed by the application of nitrous acid, as well as thoſe which are developed by fermentation and diſtillation, owe their origin to the fixation of the oxyginous principle of the water, of the nitrous acid, or of the atmoſphere in combination with oleaginous baſes. It is eaſy to conceive, that if theſe baſes be different, the ſeveral proceſſes will be attended with different acid reſults.

However, though, on the one hand, the number of vegetable acids is conſiderably increaſed in conſequence of late diſcoveries, yet the labours of many chemiſts, and in particular of Mr. Crell, ſeem to ſhew, that the acidifiable baſes of many of theſe acids differ but ſlightly from each other, and may by various methods be made to afford abſolutely the ſame ſalts, page 96, § 14. To complete my account of the vegetable kingdoms, I ſhall here explain the properties of the acids of wood, of camphor, of ſyrup, of benzoin, and of apples; and of the reſemblance, which ſome time ago was obſerved between the baſes of the acids of ſugar and of ſorrel, and likewiſe of thoſe of tartar and of vinegar.

It has long been known, that wood affords an acid liquor by diſtillation. Goetling examined the acids of birch and box in the year 1779, and obtained with ſpirit of wine, together with theſe acids, a true æther. The acid requires to be rectified by a ſecond diſtillation. Mr. de Morveau calls this the lignic acid, and denominates its neutral combinations lignites; as for example, lignites of ſoda, of pot aſh, &c.

Mr. Fontana ſuſpects that this acid may be very different according to the wood from which it has been obtained; but birch, box, and beech, have been found to afford the ſame acid. Its combinations have not yet been much examined into. Mr. de Morveau, from the trials of Mr. Eloy Bourſier de Clairveaux, affirms that calcareous and ponderous earths do not yield this acid to cauſtic fixed alkalis; that lime does not yield it to ponderous earth, nor magneſia to the pure volatile alkali.

Mr. Koſegart, by diſtilling colourleſs nitrous acid eight times ſucceſſively from camphor, has changed that combuſtible body into a peculiar bitter acid, which cryſtallizes in the form of parallelipipeds, and does not precipitate lime from other acids, as the ſaccharine acid does. This acid, denominated the camphoric acid by Mr. de Morveau, forms with the vegetable alkali, a ſalt in regular hexagons; with the mineral alkali, a ſalt in irregular cryſtals; with the volatile alkali, a ſalt likewiſe cryſtallizable; with magneſia, a pulverulent and ſoluble ſalt. It diſſolves many metals. Mr. de Morveau gives the name of camphorites to its ſaline combinations. We muſt obſerve, that this acid is not yet ſufficiently known to admit of our entering into any full account of it, or even to conſider it as perfectly diſtinct from certain other acids.

The elder chemiſts, who diſtilled ſugar and manna, obſerved that a penetrating acid was diſengaged, to which they aſcribed many ſingular properties. Lemery, Boerhaave, Hermann, and Cartheuſer, began the examination of this acid; but Mr. Scrickel has been more particularly attentive to its characters. Mr. de Morveau calls this ſalt the ſyrupous acid, and diſtinguiſhes its combinations by the names of ſyrups. This celebrated chemiſt has obſerved, that the glaſs of the retort is attacked and corroded during the diſtillation of ſugar. Mr. Scrickel rectifies this acid in earthen veſſels, and concentrates it by congelation. It is contained ready formed in ſugar, according to Mr. de Morveau, and by its ſuperabundance in molaſſes, is the cauſe of the difficulty with which that ſalt is cryſtallized. This acid, in its concentrated ſtate, is very penetrating; it quickly reddens the blue colours of vegetables; has a ſtrong ſmell, and tinges the ſkin yellow, according to Cartheuſer. In open veſſels it is driven off by fire; and in cloſed veſſels it is decompoſed, leaving a carbonaceous reſidue. Its combinations with alkaline baſes form ſalts different from thoſe of the ſaccharine acid. It diſſolves ſeveral metals. Mr. de Morveau diſpoſes its elective attractions in the following order; vegetable alkali, mineral alkali, ponderous earth, lime, magneſia, volatile alkali, clay, metallic calces, water, ſpirit of wine. We may likewiſe add, that this acid is obtained from honey, gums, farina, ſugar of milk, and all mucilaginous and ſaccharine matters by diſtillation. It ſeems to me to be formed by the action of fire, and by the decompoſition of water by oil.

The acid of benzoin, which has already been mentioned under the name of flowers of benzoin, has been examined by Scheele, and by Lichtenſtein. The firſt obtained it by lixivation, with lime water, evaporation, and precipitation, by means of the muriatic acid. It is purified by ſolution in warm water, and cryſtallization. It is ſoluble in 24 parts of boiling water. The vitriolic and nitrous acids diſſolve it, and it is eaſily ſeparated again from theſe acids by the addition of cold water. It unites with effervescence to mild alkalies, from which it diſengages the aerial acid, and forms with them peculiar ſalts, which Mr. de Morveau calls benzones. This acid contains an attenuated oil, which renders it volatile and combuſtible. It melts and is diſſipated, when expoſed in a ſpoon to the flame of a blow pipe. And it becomes hard with cryſtalline ramifications on its ſurface, if it be permitted to cool again after melting. Being kept twenty years in a half cloſed veſſel, in a dry place, no part of it appeared to have been loſt. It does not ſenſibly redden the ſyrup of violets, but it acts ſtrongly on the tincture of turnſole. Its taſte is irritating, without any very ſenſible degree of acidity. Weak nitrous acid being diſtilled from the acid of benzoin, the latter was entirely volatilized without alteration; but a concentrated nitrous acid being employed, the acid of benzoin became fluid, more fixed, and according to Mr. Hermſtadt, aſſumed the characters of the tartareous or ſaccharine acids. This laſt fact however, as Mr. de Morveau obſerves, wants confirmation. Mr. Scheele has diſcovered a combination of the acid of benzoin with volatile alkali, in the extract of urine, and the acid itſelf in the ſugar of milk.

The maluſian acid was thus named by Mr. de Morveau, becauſe, though many other ſubſtances contain it as well as acids, it is moſt eaſily, and in the greateſt purity, obtained from apples. To procure this acid diſcovered by Mr. Scheele, ſour apples are to be preſſed, and the juice ſaturated with vegetable alkali. This liquor is to be mixed with a ſolution of ſugar of lead. A double decompoſition then takes place. The acetous acid ſeizes the alkali, while the maluſian acid combines with the calx of lead. The maluſite of lead falls to the bottom, and the precipitate, after being waſhed, is treated with diluted vitriolic acid. Vitriol of lead is thus formed, and the maluſian acid is left diſengaged. The vitriolic acid muſt be added in ſufficient quantity to decompoſe all the maluſite of lead, which may be known by the freſh acid taſte of the liquor.

This acid poſſeſſes the following properties: It cannot be obtained in the concrete form. With the three alkalies it compoſes deliqueſcent neutral ſalts. With lime it forms a ſalt, affording ſmall irregular cryſtals, ſoluble in boiling water, in vinegar, and in the maluſian acid itſelf; with clay it forms a ſalt, ſcarcely ſoluble; with magneſia it unites in a deliqueſcent ſalt. It diſſolves iron; the ſolution being brown, and incapable of cryſtallization. With zink it affords a ſalt in beautiful cryſtals. The nitrous acid changes it into the ſaccharine acid. It precipitates the nitres of mercury, of lead, and of gold, in their metallic ſtate. Calcareous maluſite decompoſes ammoniacal citrate; and calcareous citrate is formed, which is inſoluble in boiling water, and in vegetable acids. The ſolution of calcareous maluſite in water is precipitated by ſpirit of wine. Laſtly, the maluſian acid is quickly deſtroyed by fire, which converts it into the cretaceous acid; this laſt ſaturates in part the baſes of maluſites, decompoſed by heat. Such are the properties which eſtabliſh the peculiar character of this acid.

Mr. Scheele has found this acid almoſt pure, or mixed with a ſmall quantity of the acid of citrons, in the juice of apples, of barberries, elder-berries, wild-plumbs, the fruits of the ſervice-tree, plumbs, &c. He likewiſe found it united with half its weight of citronian acid in gooſeberries, cherries, ſtrawberries, raſpberries, brambleberries, &c. and laſtly, he has obtained it from ſugar by means of the nitrous acid; and Mr. de Morveau obſerves, that the maluſian acid appears before the ſaccharine acid.

When four fruits contain both the acid of citrons and the maluſian acid, Mr. Scheele makes uſe of the following proceſs to ſeparate them, and to obtain the latter in a ſtate of purity. The juice of gooſeberries ſaturated with chalk gives a calcareous citrate, which being inſoluble, falls to the bottom; the ſupernatant liquor holds the calcareous maluſite in ſolution, which is ſeparated by means of ſpirit of wine; but as it always remains united with mucilage, Mr. Scheele had recourſe to another method for obtaining it in a ſtate of purity. He evaporated the juice of gooſeberries to the conſiſtence of ſyrup, on which he poured ſpirit of wine, which diſſolved the acid without acting on the mucilage. The latter, of courſe, was ſeparated by filtration: the filtrated liquor being expoſed to evaporation, and then ſaturated with chalk, the portion the citronian acid it contained was depoſited in the form of calcareous citrate, while the calcareous maluſite remained in ſolution. An addition of more ſpirit of wine precipitated it from this liquor, and he obtained the maluſian acid by diſſolving this ſalt in water, and precipitating the ſolution by acetated lead; after which the maluſite of lead was decompoſed by the vitriolic acid; the maluſian acid by this means remaining in an uncombined ſtate in the ſupernatant liquor.

Since the diſcovery of all theſe vegetable acids by Mr. Scheele, this celebrated chemiſt and Mr. Crell have obſerved an analogy between many of them. Mr. Scheele, who at firſt thought the acids of ſorrel and of ſugar very different from each other, has ſucceeded in ſhewing that they are one and the ſame acid; firſt, by removing a portion of vegetable alkali, which conceals the properties of the pure oxaline acid, in the ſalt of ſorrel, in the ſame manner as the acid of tartar is altered in cream of tartar. Mr. de Morveau calls theſe two native acids, the one tartareous acidula, and the other oxaline acidula, on account of the portion of alkali they contain. To obtain the oxaline acid in a ſtate of purity, Mr. Scheele precipitates its ſolution by the acetous ſalt of lead, and decompoſes the oxalte of lead by the vitriolic acid: the liquid oxaline acid, which floats above the vitriol of lead, affords by evaporation cryſtals entirely ſimilar to thoſe of the ſaccharine acid. 2. Mr. Scheele proves this identity in an inverſe way, by recompoſing the ſalt of ſorrel, or oxaline acidula, by pouring drop by drop a ſolution of vegetable alkali into the ſaccharine acid: During the effervеſcence, ſmall cryſtals of ſalt of ſorrel in a ſtate of great purity are depoſited. To ſucceed in this experiment, it is neceſſary to add but a ſmall quantity of the vegetable alkali; for an exceſs would form the oxalte of pot aſh, which is entirely ſoluble. This fact may be ſhewn in a convincing manner, by pouring either the pure oxaline acid, prepared by the acetous ſalt of lead and vitriolic acid, or ſaccharine acid formed by means of nitrous acid into a ſaturated ſolution of oxalte or ſacchart of pot aſh. The exceſs of the one or of the other of theſe acids regenerates ſalt of ſorrel, or oxaline acidula, which falls down. The latter, therefore, does not differ from the pure oxaline or ſaccharine acid, but by the portion of vegetable alkali it contains.

If to this very important fact of vegetable analyſis, we add the valuable experiments of Mr. Crell, who has obtained the acid of tartar from the ſpirit of wine, has converted that acid into vinegar, and into ſaccharine acid, and this laſt into acetous acid; we ſhall perceive that the ſaccharine and oxaline acids, and alſo the tartareous and acetous are very analogous to each other, being formed from one and the ſame baſe, and differing only in the doſe of the oxyginous principle contained in each. It appears that the tartareous acid contains the ſmalleſt portion,

tion, that the ſaccharine or pure oxaline acid contains much more; and that the acetous acid contains the moſt of this principle. I cannot avoid thinking, that ſince theſe four vegetable acids, formerly ſuppoſed to be ſo very different from each other, have already been proved to have the ſame baſe combined with different doſes of the oxyginous principle; we may expect by new diſcoveries to find a like analogy between many others, and eſpecially between the citronian and maluſian acid, which are ſo often found together in vegetable juices.

XIV. The ſpiritous fermentation, the ſimultaneous formation of the cretaceous acid, and of ardent ſpirit, the neceſſity of water and of a ſaccharine principle for the carrying on of this fermentation, authorize us to conclude, that the proceſs itſelf is a conſequence of the decompoſition of water. The oxyginous principle of this liquid ſeizes the carbonaceous principle, with which it forms cretaceous acid. This becomes diſengaged, and the inflammable gas remains fixed in combination with the oily baſe; which, with different quantities of the oxyginous principle, forms the tartareous, ſaccharine and acetous acids, and conſtitutes ardent ſpirit. This theory admirably explains why ardent ſpirit affords ſo large a quantity of water during its combuſtion; why it is changed by the mineral acids into the ſaccharine, acetous, &c. acids. We do not, it muſt be confeſſed, yet underſtand how it paſſes into the ſtate of æther; but it is probable that ſpirit of wine, in theſe operations, loſes a portion of its inflammable gas, and that water is formed.

XV. Chemiſts at preſent begin to form probable conjectures reſpecting all the deſiderata required by ſcience for the formation of animal matters. Digeſtion appears to be a ſimple extraction or ſolution by the gaſtric juice; the fixation of the mephitis is one of the principal functions of the animal organiſm. The mephitis appears from the reſearches of Scheele, and eſpecially Berthollet, to conſtitute the principal difference which exiſts between vegetable and animal matters, by contributing to the formation of the volatile alkali, which the latter ſubſtances give out ſo abundantly in diſtillation, and other proceſſes. It is not yet decided in what manner the mephitis becomes fixed in animals, whether by means of the ſtomach, the ſkin, &c.

The different animal fluids deſigned to maintain the various organs, the diſtinction between the gelatinous and albuminous fluids, and the fibrous parts diſſolved in certain fluids, is at preſent well eſtabliſhed. It is now well known that the firſt is the leaſt animalized ſubſtance, that the ſecond is more ſo, and that the third is the laſt product of the vital action on the fluids; that the firſt forms the ſolid parts, that the albuminous part becomes thick, and concretes by heat, while the gelatinous ſubſtance is more diſpoſed to melt, but at the ſame time more quickly re-produced. Peculiar acids have been found in the excrementitious humours, whoſe formation is unknown; eſpecially that of the phoſphoric acid, ſo abundantly and univerſally diſperſed through this kingdom.

The nature of animal ſolids has been much attended to by modern chemiſts. The difference between the fibrous parts of the muſcles, and the membranous coverings of certain parts, &c. is known. The art of medicine may expect from chemical diſcoveries the ſolution of problems relative to the formation of the ſeveral matters which conſtitute theſe parts; and eſpecially reſpecting the phoſphoric acid, the albuminous fluid, the fibrous matter, calcareous phoſphat, and the peculiar oils found in the animal kingdom. The formation of the volatile alkali ſuſpected by Bergman and Scheele, and put out of doubt by Berthollet, encourages us to hope that theſe problems will be reſolved in due courſe. It is probable that a few principal facts only are wanting to enable us to arrive at ſeveral reſults of the greateſt importance; and this hope ought to animate ſuch phyſicians as are aware of the importance of chemical enquiries.

XVI. Ever ſince the time of Lord Chancellor Bacon, the importance of chemical reſearches on putrefaction, for medical purpoſes, has been well known. Several phyſicians have buſied themſelves on this ſubject to good purpoſe; but the cauſe of this decompoſition, and the manner in which it is effected, has not yet been diſcovered. Modern experiments, however, have thrown ſome light on this important ſubject. It is ſuſpected that water, which favours, and even gives riſe to putrefaction, is decompoſed in the inteſtine motion, which conſtitutes that proceſs. The volatile alkali, ſo abundantly formed by the union of mephitis and inflammable air, is commonly very ſenſible. The ſlowneſs with which fat is decompoſed, its preſervation, and increaſed rigidity, which in certain caſes is very conſiderable, ariſes from the fixation of the pure air of water; the volatization and reduction of the elaſtic fluids, of animal ſubſtances deprived of life, expoſed to the air, and in a word, the complete ſeparation of all theſe principles, and their diſſipation in the atmoſphere, which tranſmits them to new combinations; and more eſpecially the ſucceſſion of combinations and transformations from one kingdom to the other, ſo well expreſſed by Beccher in his philoſophical motto, "circulus æterni motus," by which he expreſſes the never-ceaſing activity of nature, are among the various ſubjects we may expect to ſee explained by the enlightened chemiſtry of modern times.

ELEMENTS
OF
NATURAL HISTORY
AND OF
CHEMISTRY.

PART I.

General Facts and Obſervations.

CHAP. I.

Definition of Chemiſtry; the methods of performing operations; the advantages derived from this Science, &c.

CHEMISTS are not generally agreed on the moſt proper definition of Chemiſtry. Boerhaave, in his Elements, ſeems to have ranked it among the arts; or, to ſpeak more accurately, he has defined only the practical part. Chemiſtry, according to Macquer, is a ſcience, whoſe object is to diſcover the nature and properties of all bodies, by their analyſes and combinations; and this definition is indiſputably the beſt that has yet been given. But as it is certain that the analyſis and ſyntheſis cannot with equal ſucceſs be employed in all caſes where bodies are to be examined, would it not have been better to have omitted mentioning them in defining this ſcience? The chemiſt cannot arrive at the knowledge of the properties of bodies, but by bringing them into contact; and as the reſult is derived only from the mutual actions of bodies on each other, we think the following definition may be properly adopted: Chemiſtry is a ſcience which teaches the mutual actions of all natural bodies on each other*. The facts hereafter to be related, will illuſtrate this definition. To exhibit the extent of this ſcience with perſpicuity and order, we ſhall proceed to conſider the objects or ſubſtances to which its reſearches or operations are directed, the methods or means employed, and the advantages propoſed to be thence derived.

§ I. Concerning the object, the methods, and the intention of chemiſtry.

The objects to which the attention of the chemiſt

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[*] This is too general; as it includes mechanical actions. T.

chemiſt is directed, comprehend the whole of the ſubſtances that compoſe the globe we inhabit, whether buried in its interior parts, or found at its ſurface. Chemiſtry is, therefore, of equal extent with natural hiſtory, the ſame limits being common to both.

Analyſis, or decompoſition, and ſyntheſis, or combination, are the two methods which chemiſtry uſes to accompliſh its purpoſes. The firſt is nothing more than the ſeparation of bodies, whoſe union formed a compound ſubſtance. Cinnabar, for example, is compoſed of ſulphur and mercury; the art of chemiſtry ſeparates the two, and by that means analyzes it. Till very lately it has been generally thought, and there are ſtill many perſons who retain the opinion, that this method is more advantageous in chemical reſearches than the other. This opinion had even acquired ſuch place in the minds of the learned, that many writers have defined chemiſtry to be the ſcience of analyſis. But nothing can be more contrary to the accurate and well founded idea or degree of eſtimation we ought to have of decompoſition. In order to ſhew this important truth in its proper light, it is neceſſary to diſtinguiſh two kinds of analyſis; the true, or ſimple; and the falſe, or complicated. We call that the true analyſis, by which the principles of a body are obtained,

tained, without having themſelves ſuffered any alteration. The only diſtinguiſhing criterion of this is, that by recombining them, a body is again produced, abſolutely ſimilar to that which before was analyzed. Cinnabar will again furniſh us with an example. When by chemical methods, the two ſubſtances which enter into the compoſition of this body, namely mercury and ſulphur, are ſeparated, they are found to be in a ſtate of purity, ſimilar to that they poſſeſſed before, when united in the form of cinnabar; for, by uniting them, a body is again formed, in no reſpect differing from the cinnabar originally made uſe of. Unfortunately for the progreſs of ſcience, this kind of analyſis is very rare. Chemiſts are not ſo happy as to be able to apply it to many of the bodies they make experiments with; for except the neutral ſalts, and ſome other mineral bodies, there are no other ſubſtances in nature that admit of its application. The falſe, or complicated analyſis, is that, by means of which, no other principles are ſeparated from a body, but ſuch as in their original ſtate poſſeſſed ſome other form, and conſequently cannot, by their re-union, compoſe again the body from which they were obtained. This kind of decompoſition takes place in moſt of the bodies analyzed by chemiſts; no other condition being requiſite, but that more than two principles enter into the combination to be examined, and that they have an affinity for each other. Many minerals, and all vegetable and animal matters without exception, are capable of no other kind of analyſis. Thus it is that ſugar, ſubmitted to diſtillation in a retort, affords an acid, an oil, and a coaly reſidue, which might in vain be employed in attempts to re-produce ſugar by combination. This kind of analyſis does not ſhew the ſtate in which the principles were before their ſeparation, and cannot therefore afford any conſiderable information; but, on the contrary, deſerves to be attended to with the greateſt caution. From reſults of this kind have ariſen all the cenſure chemiſtry is loaded with. It has been urged, that bodies were deprived of their organization, and abſolutely deſtroyed in attempts to arrive at their principles. Neither can it be denied, but that this cenſure has been for a long time deſerved; but at preſent, the ſcience of chemiſtry, having become more circumſpect and enlightened, refuſes its aſſent to the deceitful analyſis to which it formerly had recourſe, and poſſeſſes the means of inquiring into the properties and component principles of bodies, without deſtroying or altering their nature.

Syntheſis, or combination, which conſtitutes the ſecond method of proſecuting chemical inquiries, the formation of a compound by the artificial re-union of ſeveral principles. Its utility, extent, and the dependance that may be placed on the reſults it affords, renders it by much the moſt valuable method. We may even affirm, that there is not a ſingle operation in chemiſtry, in which ſome combination does not take place. Chemiſts do not ſeem to have ſufficiently attended to this important circumſtance. In fact, the ſynthetical operations, or events, are not only more frequent, but more uſeful, than the analytical; and it would afford no very inadequate idea of chemiſtry, if we were rather to term it the ſcience of combination, than of analyſis.

Though theſe two methods are ſometimes employed ſeparately, it is nevertheleſs much more uſual to find them united. It often happens, that a true analyſis cannot be made, but by the help of ſome combination. Falſe analyſes, or decompoſitions, are always attended with ſynthetical proceſſes, or new combinations. In a word, it is not unuſual to find, that a kind of analyſis follows as a conſequence from certain acts of combination; an event, which has not been known till very lately. The diſcovery of a great number of aeriform fluids, whoſe exiſtence was not formerly ſo much as ſuſpected, has ſhewn, that in many operations which were ſuppoſed to be ſimple combinations, an elaſtic inviſible fluid is diſengaged with effervefcence, and either eſcapes into the atmoſphere, or is received in veſſels, in which the ingenuity of modern philoſophers has taught us how to confine it. The greater number of combinations of two ſubſtances, hitherto thought to be ſimple, exhibit this kind of analyſis; and frequent examples will offer themſelves when we come to treat of neutral ſalts.

From this curſory account of the analyſis and ſyntheſis of the chemiſts, it is eaſy to be ſeen, that the whole art of chemiſtry conſiſts in promoting the mutual actions of bodies on each other, and carefully obſerving the phenomena that take place. It muſt not be forgotten, that theſe two methods are continually practiſed in the grand operations of nature, of which the chemiſt is only an imitator. The operations all depend on laws eſtabliſhed between bodies, and require nothing more, in order to their being perfectly accompliſhed, than that the bodies to be examined be put into a ſituation proper to act on each other. Theſe important truths require to be maturely weighed and conſidered with the moſt ſerious attention, by the ſtudent who is deſirous of penetrating into the depths of chemiſtry: and theſe, together with other truths explained in this firſt part, form the baſis of the ſcience.

Hence it is very eaſy to form an idea of the end or intention of chemiſtry, which is erroneouſly ſaid to conſiſt in the diſcovery of the principles of bodies. For it is clearly ſhewn, that there are many bodies that cannot be ſeparated into principles, but are ſimple ſubſtances, as far as our preſent knowledge extends; yet theſe, though not ſuſceptible of analyſis, muſt have chemical properties, or powers of acting on other bodies, and of forming combinations with them. The true purpoſe or intention of chemiſtry therefore, is to inquire into the action of natural bodies on each other, as well and even more, by ſyntheſis than by analyſis. This conſideration ſerves completely to eſtabliſh the property and truth of our definition.

§ 2. Concerning the uſeful purpoſes to which chemiſtry is applicable.

To give a view of the numerous advantages mankind derive from this ſcience, would require a ſeparate treatiſe; and as the nature of this work does not admit of our purſuing that ſubject at large, we ſhall content ourſelves with exhibiting the principal outlines, and dwelling more particularly on ſuch ſubjects, as in our opinion have not been ſeen in a proper point of view.

The great number of arts that are indebted to chemiſtry, may be ranged under two principal diviſions. The firſt comprehends all the mechanical arts, which are reducible to geometrical principles. The ſecond contains all thoſe arts, whoſe manipulations depend on chemiſtry, and may be properly termed chemical arts. This laſt claſs is much more numerous than the other. As they are all founded on chemical phenomena, it is eaſy to imagine that the rules of chemiſtry ought to direct the practice, and that this ſcience may ſimplify the proceſſes by new diſcoveries, render their ſucceſs more certain, and even extend their limits. Among theſe are, 1. The arts of making bricks, tiles, and the varieties of pottery; all which conſiſt in the preparation of different kinds of clay, and bringing them by baking to the requiſite degree of hardneſs. 2. The art of glaſs-making, which by uniting a vitrifiable earth with a ſaline ſubſtance, produces a new ſubſtance poſſeſſing great hardneſs, tranſparency, and durability, on expoſure to the air. A wonderful art, which, in its various applications, has been of the moſt eſſential ſervice to mankind. 3. The arts of extracting metals from their ores, of caſting, of purifying, or of alloying them with each other, owe their origin and progreſs to chemiſtry, and daily receive new advantages from the ſame ſource. 4. The vegetable kingdom affords materials to a great number of arts, which, like the foregoing, are under the dominion of chemiſtry: the arts of converting ſaccharine juices, or farinaceous bodies, into vinous liquors; of extracting from thoſe liquors the ardent ſpirit they contain; of ſeparating the ſpirit from the water, with which it is diluted in its firſt ſtate; of uniting this ſpirit to the aromatic parts of plants: the art of extracting the colouring matter of plants, and applying it to different ſtuffs: of changing wine into vinegar, and uniting this laſt with various ſubſtances; of ſeparating from grain, and other parts of vegetables, the precious matter deſtined to form bread, a digeſtible and light ſubſtance prepared from a dry and inſipid farinaceous powder; all theſe arts, and a very great number of others, that cannot be enumerated in this place, are entirely chemical, and are indebted to that ſcience for their preſent perfection, and, in many inſtances, for their firſt invention.

This valuable ſcience has claims equally extenſive and important on the arts that convert the parts of animals to our uſe and advantage. Among theſe is the uſeful, though too little conſidered, art of cookery, whoſe true purpoſe is leſs to flatter the organs of taſte by capricious variations of form and flavour, than to render aliments of eaſy digeſtion, by developing their taſte by boiling, or by mild and natural ſeaſoning. Some readers will, doubtleſs, be ſurpriſed to find the art of cookery, which is ordinarily thought of ſo ſmall conſequence, placed in the rank of thoſe which chemiſtry is capable of advancing. It will be ſufficient on this occaſion to anſwer, that all the proceſſes uſed in the preparation of food are chemical; and that it is not beneath the chemiſt, to pay ſome attention to an art that ſo materially affects the health. The arts of dreſſing, taning, and currying ſkins, and of making hats, are of the ſame claſs; but one of the moſt important arts which occupies the middle rank between the arts, properly ſo called, and the ſciences, is pharmacy. Every perſon concerned in pharmacy, has need of a very extended knowledge of chemiſtry, in order to know the alterations the matters he uſes are ſubject to, that he may prevent and correct them; to diſcover the changes compound medicines undergo; and, in a word, to determine inſtantly, the combinations and decompoſitions that may follow from the mixture of ſimple drugs in extemporaneous preſcriptions. Every impartial perſon who reflects on this ſubject, will determine, that ſuch as are neceſſarily employed in pharmacy ſhould, after acquiring the previous knowledge of natural hiſtory, indiſpenſable in becoming acquainted with the Materia Medica, pay the moſt ſerious and unremitted attention to chemiſtry. By theſe means, and by theſe alone, it is, that the art of medicine can be reduced to principles,

ciples, and rendered equal to the performance of thoſe ſervices, which have long ſince placed it in the honourable eſtimation of ſociety.

A very tranſient proſpect of the ſciences, will ſufficiently ſhew the great benefits to which they may derive from chemiſtry. Natural hiſtory is among thoſe that receive the higheſt advantages from it. The characters employed by the early naturaliſts to diſtinguiſh minerals, were taken only from their phyſical properties, as colour, form, conſiſtence, &c.; but theſe properties being ſubject to great variation, the bodies mentioned or deſcribed by the ancient philoſophers are no longer known, and the immenſe labours of the firſt naturaliſts are almoſt entirely loſt. The moderns have perceived, that in order to avoid this inconvenience, ſo deſtructive to the progreſs of natural hiſtory, it was neceſſary to follow another method. The method of chemical analyſis appeared to deſerve the preference; and the buſineſs is already in ſuch forwardneſs, that claſſes are eſtabliſhed among minerals, founded on the nature and quantity of the principles which enter into their compoſition. It is to the labours of Meſſrs. Bergman, Bayen, Monnet, &c. that we are indebted for the advancement of this part of natural hiſtory. Wallerius, Cronſtedt, and ſeveral other learned men, began the taſk of claſſing mineralogy upon chemical principles. M. Bucquet, in his latter courſes of lectures, improved on the knowledge theſe two celebrated naturaliſts have tranſmitted to us, by adopting a method of claſſing minerals, on principles entirely chemical. M. Sage, who has analyzed a great number of minerals, has followed a method purely chemical in his diſpoſition of theſe bodies; and, though his theory is not yet univerſally received, it is certain that mineralogy is under great obligations to him; and that he ranks among thoſe who have cultivated it with the greateſt ſucceſs in France. M. Daubenton has availed himſelf of the labours of all his cotemporaries, and has adopted their methods and concluſions with that caution, which is the true character of a philoſopher, whoſe only aim is to diſcover and obtain the truth, ſeparated from the numerous uncertainties and errors, with which, unhappily for mankind, it is too often attended. Nothing, therefore, can be ſhewn more evidently, than the advantages reſulting from the application of chemiſtry to natural hiſtory, as it is the only means of removing that obſcurity that muſt attend ſimple deſcriptions of external appearances. The juſt and truly valuable obſervation of M. Daubenton, deſerves to be conſtantly attended to by all chemical philoſophers. He warns them to be very careful in deſcribing the ſpecimens on which they make their experiments, in order that they may be underſtood by all naturaliſts, and to avoid that confuſion, which, according to that celebrated profeſſor, prevails throughout the works of many modern chemiſts. M. Bucquet, and myſelf, have found no other means of avoiding this error, than that of uniting both ſciences in our lectures, and aſſociating the knowledge obtained from the works of naturaliſts, with that which chemical experiments daily produce.

It is not ſo clearly determined in the opinion of the world in general, that chemiſtry is uſeful in medicine. The errors of the chemical phyſicians of the laſt century, and the indifference many practitioners of the preſent time ſeem to have for this ſcience, have produced a diſadvantageous opinion in the minds of many perſons, which time alone can remove. In the mean time, however, it would be more prudent, inſtead of entertaining an ill-founded prejudice, to inquire with impartiality into the cauſe of the errors committed by chemiſts, into the means of preventing them, and of reſtoring to chemiſtry that eſtimation it has unjuſtly been deprived of. If the enthuſiaſm of the firſt phyſicians, who cultivated chemiſtry, miſled them, it does not follow that any concluſion can be drawn from thence that may be applied to the preſent time. The exactneſs which the moderns have introduced into every part of experimental philoſophy, ought to remove the apprehenſions of ſuch, as for want of acquaintance with the ſubject, are apt to imagine that chemiſtry is ſtill the dark, myſterious ſcience it was a century ago. By a due attention to the extent of its powers, and a careful uſe of them, there cannot be a doubt but it will be found of the higheſt utility to medicine. After this acknowledgment of the wanderings of the early chemiſts, let us finiſh the juſtification of the ſcience, by enquiring what departments of medicine are capable of deriving the greateſt advantages from its aſſiſtance. The two great branches of this vaſt ſcience, are theory and practice; which ought not to be ſeparated from each other, as ſome authors have thought fit to do. The ſtudy of medicine ought neceſſarily to commence with the anatomical hiſtory of man, and of animals. Anatomy can only be employed on the ſolids. But phyſiologiſts muſt be well aware, that the greateſt part of animal bodies is formed of fluids; by the motion of which, life is maintained. If therefore the attention were confined to the veſſels, without attempting to arrive at the nature and properties of theſe fluids, we ſhould be acquainted only with a part of the living œconomy. It belongs to chemiſtry to examine them; and it is chemiſtry alone, that can throw any light on their compoſition,

tion, and the changes they undergo, by the proceſſes there are carried on during life. We cannot avoid having recourſe to this ſcience, in our endeavours to diſcover the true mechaniſm of the animal functions; the properties of the fluids ſeparated by the different viſcera; or the alterations ſuch fluids undergo, during their time of remaining in the reſervoirs into which they are ſecreted. A knowledge of the compoſition of animal fluids being once acquired, it will be neceſſary to enlarge and multiply our reſearches on ſubjects of different age, ſex, and temperament, in various climates and ſeaſons; and to purſue them among the different claſſes of animals; that by eſtabliſhing uſeful points of compariſon, the limits of ſcience may be extended.

The labour of the medical inquirer is not confined to the ſtudy and examination of the properties of animal fluids in a ſtate of health; but requires to be carried farther. The kinds of alterations they are ſubject to, in the ſeveral diſorders that afflict the human frame, muſt be inquired into. A diſcovery what part of the animal liquids predominate in inflammatory, putrid, ſcorbutic, or ſcrophulous diſorders; or the analytical knowledge of the ſaline ſubſtances developed, and the nature of the extravaſated matter, with numberleſs other objects of reſearch, cannot but be of the utmoſt value and importance in the ſcience of medicine. We think it equally neceſſary to examine the ſolids, by chemical methods, as well in the ſound as in the diſeaſed ſtate, and, by a compariſon of their properties, endeavour to diſcover to which of the fluids they owe their formation; and this being known, we may proceed to conjecture in morbific diſpoſitions, the ſolid or fluid that has ſuffered a change. This poſition, which we ſlightly mention in this place, will be more largely explained in the chapters relating to animal matters.

If it be thus eſtabliſhed, that the theory of medicine is capable of receiving the moſt eſſential advantages from chemiſtry, it is equally certain that the practice is no leſs in need of the ſame aſſiſtance; ſince both muſt of neceſſity accompany each other, and are promoted by the ſame means. And, in fact, it is eaſy to ſhew the immediate dependence of the practice upon the ſcience we are juſtly commending, without having recourſe to the ſecondary advantage the practical part of medicine cannot but receive from every real improvement of the theory. To begin with the art of preſerving health: nothing can be more evident than that the choice of aliments, and of air, cannot be made with any certainty, but in conſequence of chemical reſearches into the nature of foods, and the properties of the atmoſpheric fluid. Chemiſts alone can inform us of the quantity of nutritive matter contained in the aliments we make uſe of; the ſtate it is found in; the nature and quantity of the ſubſtances it may be combined with; the means of extracting, purifying, and preparing it, ſuitably to different ſtomachs; or of giving it the due degree of attenuation appropriated to every conſtitution of the internal parts. It is to this ſcience that we muſt apply for information, reſpecting the nature of the fluids that ſerve us for drink; the properties which water ought to poſſeſs for the purpoſes of life, and the means of examining into its purity, or diſcovering thoſe ſubſtances that vitiate it; the principles and properties of fermented liquors; and the methods of examining into their compoſition, as well to determine their ſalubrity, as the adulterations which they may have undergone. In a word, it is chemiſtry which ſhews the properties of the air which we reſpire, and without which, life could not for a moment be ſupported. The changes this ſubtle fluid is liable to, from various agents, and the nature of thoſe agents, the truly precious means of correcting its bad qualities, and rendering it fitter for the grand purpoſe of reſpiration, are among the diſcoveries of modern chemiſts.

The phyſician ought not to make uſe of

medicines, unleſs he is acquainted with their nature; and in the inquiry, he muſt have recourſe to chemiſtry. This truth has been always ſo well eſtabliſhed, that writers on the Materia Medica have claſſed the medicaments according to their chemical principles. The obſervation of all ages has ſhewn, that there is an intimate connection between the taſte of drugs, and the manner of their acting on the human frame: ſo that a good judgment may be formed of the medical properties of a ſubſtance from its taſte. Thus it is that bitters are ſtomachic, inſipid ſubſtances are mild and relaxing, and acid matters are active, penetrating, and inciſive. Now, as the taſte is truly a chemical property, depending entirely on the tendency of bodies to combination, as we ſhall elſewhere ſhew, chemiſtry muſt of courſe be of great ſervice in the adminiſtration of medicines. It muſt not, however, be concluded according to the chemiſts of the laſt century, that the ſtomach reſembles a veſſel, in which operations are performed as in a chemical laboratory; where acids, for example, meet and efferveſce with alkalis. The inteſtines are endued with ſenſibility, and a peculiar motion, that modify the nature and effects of remedies; and the diſcretion of an enlightened obſerver, ought always to regulate his imagination, ſo as to prevent his falling into any ridiculous hypotheſis. It cannot be denied, but there are caſes wherein medicines act in the firſt paſſages by means of their chemical properties; and in theſe caſes the phyſician may reaſon and conduct himſelf according to immediate deductions from chemical principles. Thus it is proved, by long experience, that in the diſeaſes of infants, the ſtomach and inteſtines are coated with a tenacious viſcous matter, of a manifeſtly acid nature. The abſorbent earths, and even the alkalis adminiſtered on ſuch occaſions, deſtroy this acid by combining with it, and form a neutral purgative ſalt that evacuates this noxious matter, by ſtimulating the inteſtines. Every diſorder which is attended with an accumulation of obſtructing matter in the firſt paſſages, neceſſarily demands a knowledge of chemiſtry in the exhibition of medicines. But the greateſt advantage the practitioner can derive from this knowledge, is, without doubt, in thoſe unhappy caſes, wherein by miſtake or deſign, corroſive ſubſtances have been taken that might prove mortal by attacking the viſcera, and deſtroying their organization. Chemiſtry then lends its ready and ineſtimable aid to medicine, by affording ſubſtances capable of changing the nature of the poiſon by decompoſition; or of otherwiſe immediately ſtopping its pernicious effects. The work of M. Navier, a celebrated medical chemiſt of Chalons, points out the moſt efficacious means of preventing the deſtructive conſequences of the poiſons of arſenic, corroſive ſublimate, verdegriſe, and the preparations of lead; and notwithſtanding the declamations of certain phyſicians, who ſeem deſirous of excluding the ſciences from the practice of medicine, his work will receive the tribute of gratitude from poſterity.

Chemiſtry is not adequate to the counteracting the effects of all poiſons, but there is good reaſon to hope that reſearches into the nature of vegetable and animal poiſons, if made with ſkill and care, would be attended with the diſcovery of remedies of ſufficient power to counteract them. Opium, and all narcotic vegetables, the acid and cauſtic juices, ſuch as thoſe of ſpurge and euphorbium, the noxious plants, and more eſpecially the fungi, demand the particular attention of chemiſts, for the diſcovery of ſubſtances proper to obviate their dangerous effects. With no leſs utility, an inquiry might be made into the animal poiſons. We are already acquainted with the acid of ants, from the experiments of Margraaf and Fontana. Thouvenel has diſcovered ſeveral acrid matters in cantharides. Mead has made reſearches on the poiſon of the viper. Fontana has purſued the ſame ſubject, and has diſcovered that the lapis cauſticus immediately introduced into the wound made by this reptile, decompoſes or alters the poiſon, and prevents its deadly effects.

If it be poſſible, after what has been ſaid, to ſuppoſe that chemiſtry is not equal to the performance of the deſirable effects here pointed out, yet no one can deny that the ſcience of medicine is indebted to it for many uſeful remedies. It can never be forgotten that ſtibiated tartar, with all the mercurial, antimonial, and martial preparations which are poſſeſſed of ſuch power and efficacy, are the products of chemiſtry; and that the gratitude and encouragement of medical profeſſors, as well as the public in general, is due to ſuch as devote themſelves to its improvement.

To conclude our obſervations on the utility of chemiſtry to medicine, we ſhall only add, that a knowledge of the former is neceſſary, in order to draw up a preſcription for any compound medicine to be made up by the apothecary. It happens daily, that perſons unacquainted with chemiſtry, commit the groſſeſt errors in their extemporaneous formulæ, by mixing together ſubſtances that either become changed by mutual decompoſition, or elſe refuſe to unite at all. In the caſe of decompoſition, the medicine cannot produce the effect, which the phyſician from his acquaintance with the component matter, was led to expect. Such errors, ſo prejudicial to the health of the patient, are no otherwiſe to be avoided, but by a knowledge of chemiſtry, which is the only guide in the preparation of remedies. Without this guide, the phyſician is not only liable to the occaſional faults we have pointed out, but to numberleſs others, which though of leſs eſſential conſequence, muſt expoſe his ignorance to the apothecary; who, in the practice of his own art, cannot but be acquainted with a conſiderable number of chemical facts.

The uſefulneſs of chemiſtry in the arts, and the reſemblance between its proceſſes and the manipulations of artiſts, have often cauſed it to be confounded either with alchemy or pharmacy, by perſons ignorant enough to unite objects in their own nature ſo remote from each other. In the opinion of ſuch, the chemiſt is an artiſt inceſſantly employed in the vain ſearch of the philoſopher's ſtone. But thoſe who have acquired the leaſt knowledge of true chemiſtry and its purpoſes, will readily perceive the immenſe diſtance between the ridiculous and abſurd pretenſions of the alchemiſt, and the enlightened chemiſt; and more eſpecially the difference between the regular proceedings of the latter, compared with the inconſiſtent and uſeleſs proceſſes of the former. The error of the many, who regard chemiſtry as the art of preparing drugs, is much more pardonable; becauſe it does not confound chemiſts with the ignorant, and, at beſt, the uſeleſs operators of what is called the Grand Work, who, as Macquer ingeniouſly obſerves, are the workmen of an art that has no exiſtence; but aſſociates them with a reſpectable claſs of artiſts, whoſe labours are neceſſary to ſociety. But pharmacy being nothing more than a part of chemiſtry, or one of the many arts that are dependent on, or benefited by, its principles, the perſon who regards chemiſtry as the art of preparing remedies, will have but a very limited idea of this experimental ſcience: a ſcience of ſuch ſublimity and vaſt extent, that it not only contains within itſelf the much greater part of the numerous arts that diſtinguiſh civilized nations from ſavages, but extends its reſearches univerſally to the mutual actions of the component parts of bodies on each other; to the great improvement of natural philoſophy, which in many of its moſt important parts is purely chemical.

CHAP. II.

The Hiſtory of Chemiſtry.

HE who devotes himſelf to the ſtudy of any ſcience, ought not to be ignorant of the outlines of its hiſtory. For ſuch a hiſtory, being a relation of ſcientific facts, fixes the dates of diſcoveries, points out the errors of our predeceſſors, and indicates the path that leads to ſucceſs. But as it might not tend to promote the immediate purpoſe of this treatiſe, if we were to dwell on ſubjects that are in ſome meaſure foreign to it, we ſhall exhibit nothing more than the outlines of this hiſtory; without entering minutely into particulars, which may be found at length in many well written books. In particular the treatiſe of Olaus Borrichius de ortu et progreſſu chemiæ, the article Chimie in the Dictionnaire Encyclopedique, the diſcourſe at the head of Senac's Chemiſtry, l'Hiſtoire de la Philoſophie Hermitique by the Abbe Lenglet du Freſnoy, the firſt chapter of Boerhaave's Chemiſtry, the preliminary diſcourſe to Macquer's dictionary, &c. may be conſulted for this purpoſe.

For the purpoſe of exhibiting in a conciſe and methodical manner, the progreſs of the human mind in the ſtudy of chemiſtry, and the ſeveral advances made therein from time to time, we ſhall divide our hiſtory into ſix principal epochas.

EPOCHA THE FIRST.

The origin of Chemiſtry among the Egyptians, and its progreſs among the Greeks.

The origin of chemiſtry is not leſs obſcure than that of the other ſciences and arts in general. The patriarch Tubal Cain, who lived before the deluge, is ſaid to be the firſt chemiſt; but his knowledge is not affirmed to have extended beyond the working of metals. This man ſeems to have been the ſame, who is ſpoken of in fabulous hiſtory under the name of Vulcan.

It is among the Egyptians that we ought to place the true origin of this ſcience. The firſt of this nation, of whom mention is made as a chemiſt, is according to Lenglet du Freſnoy, Thoth or Athotis, ſurnamed Hermes or Mercury. He was the ſon of Mezraim, or Oſiris, and grandſon of Cham. He became king of Thebes.

The ſecond king of Egypt, who was likewiſe a philoſopher, was named Sephoas. He lived 800 years after Athotis, and 1900 before Jeſus Chriſt. The Greeks have given him the ſurname of Hermes, or Hermes Triſmegiſtus. He is the ſecond Mercury, and is eſteemed as the inventor of natural philoſophy. Several hiſtorians have tranſmitted to us the titles of his works on philoſophy, which conſiſted of forty-two books. It does not appear that any of them treated of chemiſtry, though the ſcience has been called after him, the Hermetic Philoſophy.

Our information reſpecting the cultivation of chemiſtry in Egypt, is very uncertain. It ſeems, however, that this ſcience made great progreſs in that country, ſince the Egyptians were in poſſeſſion of a great number of chemical arts; and in particular, that of imitating precious ſtones; of caſting and working metals; of painting on glaſs, &c.; but the chemiſtry, as well as the other arts and ſciences of this ancient people, are loſt. Their prieſts concealed them from the vulgar as myſteries, and only recorded them under the veil of hieroglyphics. The alchemiſts have perſuaded themſelves that ſome traces of their pretended art is to be found among theſe; and that the temple, which the Egyptians conſecrated to Vulcan, was in honour of alchemy.

The Iſraelites learned chemiſtry from the Egyptians. Moſes is placed in the number of chemiſts, becauſe of the knowledge by which he was enabled to diſſolve the idol of gold that people adored. It has been thought, and Stahl has written a diſſertation to prove it, that this ſolution of gold in water was performed by the help of liver of ſulphur; a proceſs which ſuppoſes a knowledge of chemiſtry of conſiderable extent.

Democritus of Abdera, who lived about 500 years before Chriſt, travelled into Egypt, Chaldea, Perſia, &c.; and it is affirmed, that he became acquainted with chemiſts in the firſt of theſe countries. Though the ſon of a man ſufficiently rich to receive and entertain Xerxes and all his attendants, he returned very poor to his own country, where he was received by his brother Damaſſus. In his retirement in a garden, near the walls of Abdera, he employed himſelf in reſearches into the nature of plants and precious ſtones. Cicero affirms, that in order that he might not be diſturbed from his ſpeculations by external objects, he deſtroyed his ſight, by keeping his eyes for a time fixed on the bright reflection of the ſolar rays, from a veſſel of poliſhed copper; a fact which, however, is denied by Plutarch. Pliny had ſo great a degree of eſteem and veneration for the knowledge of Democritus, that he even thought it miraculous.

There are ſome authors who reckon Cleopatra among the chemiſts, becauſe ſhe knew how to diſſolve pearls. They affirm, that the art of chemiſtry, well known to all the

Egyptian prieſts, was conſtantly practiſed by that people, till the time of Diocleſian, who according to Suidas, thought fit to cauſe their books to be burned, that he might ſubdue them with more facility.

EPOCHA THE SECOND.

The Chemiſtry of the Arabians.

After a long ſeries of ages, during which it is not poſſible to follow the progreſs of chemiſtry through the revolutions of empires, we find ſome traces of this ſcience among the Arabians, who cultivated it with ſucceſs.

During the dynaſty of the Achemides or Abaſſides, the ſciences, which had been long abandoned, were reſtored to their vigour. Almanzor, the ſecond Califf, devoted himſelf to aſtronomy. Harum Raſchid, the fifth Califf, and cotemporary with Charlemagne, cauſed ſeveral books relating to chemiſtry to be tranſlated from the Greek.

In the ninth century, Geber of Thus, in Chorazan, a province of Perſia, wrote three works on chemiſtry, in which we find things treated in a very confined manner. His beſt treatiſe is intitled, Summa perfectionis magiſterii. He has written with conſiderable perſpicuity on diſtillation, calcination, and the reduction and ſolution of metals.

In the tenth century, Rhaſes, a phyſician of the hoſpital at Bagdat, firſt applied chemiſtry to medicine. Some of his pharmaceutic preſcriptions are ſtill in eſteem.

In the eleventh century, Avicen, a phyſician, likewiſe applied chemiſtry to medicine. His merit and knowledge raiſed him to the charge of Grand Vizier; but the debauched life he led was the cauſe of his being degraded from that office.

EPOCHA THE THIRD.

The tranſition of Chemiſtry from the Eaſt to the Weſtern parts of the world during the Cruſades. The reign of Alchemy.

The art of making gold was in requeſt for a long time, according to the authors who have written concerning it; but the folly which gave birth to it was at its heighth during the interval between the eleventh and ſixteenth centuries. The chemical facts diſcovered by the Egyptians, collected by the Greeks, and applied to medicine by the Arabians, came to the knowledge of the four nations who travelled into the eaſt during the cruſades; namely, the Germans, Engliſh, French and Italians; and each of theſe nations became immediately filled with ſearchers after the philoſopher's ſtone. As the immenſe labours to which they devoted themſelves have contributed greatly to the advancement of chemiſtry, it is neceſſary to be acquainted with ſuch of theſe extraordinary men as have moſt diſtinguiſhed themſelves.

During the thirteenth century, Albert the Great, a Dominican of Cologn, and afterwards of Ratiſbon, acquired the reputation of being a magician, and has left a work full of alchemical proceſſes.

Roger Bacon, born in 1214, near Ilcheſter, in the county of Somerſet, ſtudied at Oxford. He repaired to Paris to ſtudy the mathematics and medicine. Many inventions are attributed to him; any one alone of which would have been ſufficient to have rendered his name immortal. Among theſe are the camera obſcura, the teleſcope, gunpowder; he is affirmed to have made a ſelf-moving chariot, a ſpeaking head, a flying machine, &c. He was a cordelier, and was ſurnamed the admirable doctor. An accuſation of magic being preferred againſt him, cauſed his brethren to impriſon him. He retired to a houſe near Oxford, where it is ſaid he worked in alchemy. Borrichius ſaw the houſe, which was ſtill known by his name. *

Arnold of Villeneuve, born in Languedoc, in 1245, and died in 1310, ſtudied medicine at Paris during 30 years. He wrote a commentary

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* This houſe, as I am informed, was ſtanding a few years ſince. T.

tary on the epiſtle of the Schola Salernitana. The alchemiſts eſteem him as one of their greateſt maſters. Borrichius in the year 1664, ſaw one of his deſcendants, an alchemiſt, in Languedoc.

The fourteenth century. Raymond Lullius was born at Majorca in 1235, came to Paris in 1281, where he became the diſciple of Arnold de Villeneuve. Robert Conſtantin affirms to have himſelf ſeen one of the Roſe Nobles that were ſtruck in the tower of London, out of the gold made by him, during the reign of Edward the fifth, in the years 1312 and 1313. He wrote ſome books on alchemy, in which are to be found ſome facts concerning the preparation of acids, or aqua fortis, and on the properties of metals.

The fifteenth century. Baſilius Valentinus, a Benedictine of Erfort in Germany, was well acquainted with medicine and natural hiſtory. He compoſed a book on antimony, to which he gave the pompous title of "Currus Triumphalis Antimonii," which was commented on by Kerkringius. In this book we find a great number of antimonial preparations that have ſince been offered to the world under different new names, and have been adminiſtered in the cure of diſorders with great ſucceſs.

Iſaacus Hollandus the father, and his ſon of the ſame name, have written books praiſed by Boerhaave, from which it appears, that they were acquainted with the properties of aqua fortis, and aqua regia.

All theſe authors have in general written in the moſt obſcure and confuſed manner on the chemical art; and though they were acquainted with ſome proceſſes of diſſolution, extraction, purification, &c. their pretenſions were greatly beyond their knowledge, and ſcarcely any advantage can be derived from their labours.

EPOCHA THE FOURTH.

The univerſal Medicine; Pharmaceutic Chemiſtry; Alchemy oppoſed, from the ſixteenth to the middle of the ſeventeenth century.

The bad ſucceſs of the alchemiſts, and the ruin of their fortunes and reputation, were ſo far from diſcouraging chemical enterprizes, that we find a prodigious number of perſons during the ſixteenth century, encouraged and ſupported by the enthuſiaſm of a Swiſs phyſician, named Paracelſus, who was born near Zurich, in 1493. This impetuous man pretended that there exiſted an univerſal remedy. He ſubſtituted chemical medicaments in the ſtead of thoſe of the Galenical pharmacy then in uſe, and cured many diſorders by mercurial preparations, which were then deemed ſcarcely curable, more eſpecially thoſe of the venereal kind. His miraculous cures ſeemed prodigious; but tranſported by ſucceſs far beyond the bounds within which he ought to have confined himſelf, he publicly burned the books of the Greek phyſicians. He died in the midſt of his triumphs in an inn at Saltzburgh, at the age of 48 years, after having promiſed himſelf immortality by the uſe of his ſecrets.

This folly, highly extravagant as it was, revived the ardour of the alchemiſts. Some among them, who vainly imagined they had ſucceeded in the diſcovery of the univerſal medicine, dignified themſelves by aſſuming the new title of adepts. Such were, at the commencement of the ſeventeenth century,

1. The Roſicrucians, a kind of ſociety formed in Germany, of which nothing more was ever known in France but the title, and whoſe numbers continued unknown. Theſe pretended brothers affirmed, that they were in poſſeſſion of the ſecrets of tranſmutation, of the univerſal ſcience, and medicine; with the ſcience of occult things, &c.

2. A Coſmopolite, named Alexander Sethon, or Sidon, who performed the work of tranſmutation before a perſon of the name of Hauſſen. This laſt related the fact to Vander Linden, the grandfather of the phyſician of that name, who collected a medical library.

3. Another named Thomas de Vagan, born in England in 1612. He travelled into America, where Starkey received gold from him. He correſponded with Boyle. This is the ſame adept, who in France gave his powder of projection to Hevelius. The latter, after this pretended miracle, which was nothing more than an artful trick, wrote a diſſertation "De vitulo aureo, &c."

The ſucceſs that attended the adminiſtration of chemical medicines by Paracelſus, was productive however of ſome permanently good effects; for it induced ſeveral men of abilities to enter into the inquiry, and to write uſeful works on the preparation of chemical medicines. Such are the writings of Crollius, Schroder, Zwelfer, Glaſer, Tachenius, Lemery, &c. and the Pharmacopeiæ, publiſhed by ſeveral faculties of medicine.

Glauber, a German chemiſt, about this time rendered an eſſential ſervice to chemiſtry, in examining the reſidues of operations, which former operators had always thrown aſide as uſeleſs, and diſtinguiſhed by the names of caput mortuum, or terra damnata. By this means he diſcovered the ſalt named after him, and the vitriolic ammoniac; and threw great light on the chemical proceſſes for preparing mineral acids, &c.

Some of the promoters of chemical ſcience ſubſequent to Paracelſus, were not entirely cleared of the ideas his ungoverned imagination gave birth to. Such were Caſſius, known by his precipitate of gold; Sir Kenelm Digby, who believed in the ſympathetic action of medicaments. Libavius, whoſe name is affixed to a preparation of tin. Van Helmont, famous for his opinions in medicine, and the chemical notions he has propagated. And, laſtly, Borrichius, a Daniſh phyſician and chemiſt, who firſt diſcovered and publiſhed the method of inflaming oils by the nitrous acid, and is entitled to the reſpect and gratitude of the world for having bequeathed his library and chemical laboratory to the uſe of indigent ſtudents of medicine.

Alchemy, at that time, was in great danger from two celebrated men, who ſucceſsfully combated its tenets. The one was the famous Kircher, a Jeſuit, to whom we are indebted for a grand and ſublime work intitled, Mundus Subterraneus; the other was the learned phyſician Conringius.

EPOCHA THE FIFTH.

The origin and progreſs of Philoſophical Chemiſtry, from the middle of the ſeventeenth to the middle of the eighteenth century.

Chemiſtry had not hitherto been treated philoſophically. The chemical arts had been deſcribed, medical formulæ had been given, and the nature of metals had been laboriouſly inquired into with a view to the making of gold, or of the univerſal medicine; (deluſive views which ſtill miſlead the ignorant and enthuſiaſtic) but nothing more had been done. The facts aſcertained were many, but no one had yet collected them, and, as the celebrated Macquer happily obſerves, there were many branches of chemiſtry in being, though the ſcience itſelf was not yet in exiſtence.

Towards the middle of the ſeventeenth century, James Barnet, phyſician to the king of Poland, arranged the principal known facts in a methodical manner, and added obſervations in his philoſophical chemiſtry. The book of this learned man is the more valuable on account of his being the firſt perſon who attempted to form a complete body of chemiſtry, and ranked it among the ſciences.

Bohnius, Profeſſor at Leipſic, likewiſe compoſed a book of ſcientific chemiſtry, which had great ſucceſs, and was for a long time the only elementary book on this ſubject.

Joachim Beccher of Spires, a man of the moſt extenſive genius, phyſician to the elector of Bavaria, went far beyond the two authors laſt ſpoken of, and cauſed even their names to be forgotten. In his ſublime work, entitled "Phyſica Subterranea," he united all the known facts of chemiſtry, and deſcribed them with aſtoniſhing ſagacity. He has even pointed out by conjecture, a great part of the diſcoveries made to this day; ſuch as the aeriform ſubſtances; the poſſibility of reducing animal bones into a tranſparent glaſs, &c. This work was commented on by a celebrated phyſician, whoſe name fixes a moſt brilliant epocha of chemiſtry. J. Erneſt Stahl, born with a ſtrong paſſion for chemiſtry, undertook to comment and improve the doctrine of Beccher. His attention was more particularly directed to aſcertain the exiſtence of the inflammable earth, which he called phlogiſton. Equal to Beccher in genius, but ſuperior in accuracy of operation and order of reſearch, he compoſed a treatiſe on ſulphur, a work on ſalts, and another, entitled Trecenta Experimenta, which have gained him immortal glory, and placed his name among the firſt of his age.

Boerhaave, in the midſt of numberleſs occupations, cultivated chemiſtry, and compoſed a celebrated and truly profound work on this ſcience. His treatiſes on the four elements, and eſpecially that on fire, are maſter-pieces to which it is ſcarcely poſſible to make any addition. He was likewiſe the firſt who attempted the analyſis of vegetables, and diſcovered the ſpiritus rector, &c.

The theory of Stahl has been followed by the whole chemical world, and received a new acceſſion of ſtrength from the two celebrated brothers M. M. Rouelle, whoſe too early loſs is ſeverely felt by the ſcience, and to whom chemiſtry owes its origin in France.

The illuſtrious Macquer, who will be long lamented by every lover of ſcience, has contributed in a moſt eminent degree to the advancement of this ſcience by his moſt excellent works, which are with the greateſt juſtice eſteemed in every part of Europe, as the ſureſt guides to chemiſtry. Beſides the great obligations the world is under to him for his Elements and Chemical Dictionary, his own particular labours and diſcoveries on arſenic, Pruſſian blue, dying ſilk, on clays for pottery, &c. are ſufficient to immortalize his name, and entitle him to the gratitude of poſterity.

EPOCHA THE SIXTH.

Pneumatic Chemiſtry; the preſent time.

Stahl, intirely buſied in demonſtrating the exiſtence of phlogiſton, and following it through all its combinations, ſeems to have overlooked the influence of the air in the greateſt

greateſt part of the phenomena in which he attributes ſo great an energy to the inflammable principle. Boyle and Hales had nevertheleſs already proved the great neceſſity of attending to this fluid, in the operations of chemiſtry. The former had obſerved the difference between the chemical events that happened in like circumſtances in the air and in vacuo. The latter had obtained from a great number of bodies a fluid which he ſuppoſed to be air, but in which however he had obſerved ſeveral peculiar properties, ſuch as odour, inflammability, &c. according to the various ſubſtances they proceeded from. He thought the air was the cementing principle, or cauſe of ſolidity in bodies.

Dr. Prieſtly, in repeating a great part of the experiments of Hales, has diſcovered many fluids, which, though they reſemble air, differ from it in all their eſſential properties. And in particular, he obtained from metallic calces a kind of air, much purer than that of the atmoſphere.

M. Bayen, a chemiſt ſo juſtly celebrated for the exactneſs of his operations and experiments, examined the calces of mercury, and diſcovered that they were reducible without phlogiſton, and that during reduction they emitted an aeriform fluid in great abundance.

M. Lavoiſier proved very early, by a great number of valuable experiments, that a portion

tion of the air becomes combined with ſuch bodies as are calcined or burned. In conſequence of this, he eſtabliſhed a ſect or claſs of chemiſts, who began to doubt the preſence of phlogiſton, and attributed to the fixation of air, or its diſengagement, all the phenomena that Stahl ſuppoſed to depend on the ſeparation or combination of phlogiſton. It muſt be granted, that this doctrine has the advantage over that of Stahl in its proofs, being more ſtrict, and is ſo much the more ſeducing, as it agrees better with the accurate and rigorous manner of proceeding, which is at preſent adopted in the ſtudy and cultivation of natural philoſophy. This ſeemed to be the caſe in the opinion of the late M. Buquet, who in his two or three laſt courſes appeared to give it the preference. The wiſeſt, and doubtleſs the only proper conduct to be purſued on this occaſion, is to wait till a great number of facts ſhall have completely demonſtrated, that all the phenomena of chemiſtry are explicable according to the pneumatic theory, without admitting phlogiſton. M. Macquer, though well aware of the great revolution theſe new diſcoveries could not but occaſion in chemiſtry, did not admit the opinion, that every fact is explicable without ſuppoſing the exiſtence of an inflammable principle; and inſtead of phlogiſton, whoſe exiſtence has never been fairly proved, he has ſubſtituted light, the action and influence of which in chemical appearances cannot be called in queſtion.

Strongly impreſſed with a conviction of the propriety and neceſſity of purſuing this mode of conduct, we ſhall be careful to explain both theſe doctrines: and confining ourſelves to our province of the hiſtorian, we ſhall take no other liberty than that of remarking which theory ſeems to us to have the greateſt probability of being true, in the facts to which we muſt neceſſarily apply them.

CHAP. III.

Concerning the Chemical Affinities.

IN the foregoing chapter we have obſerved, that the means uſed in the performance of chemical operations, which are in general referable either to analyſis or ſyntheſis, are founded in nature; and that chemiſts are no more than imitators. This truth will be more ſtrongly eſtabliſhed by the explanation of the chemical affinities which we are about to give.

The leaſt progreſs in the ſtudy of natural philoſophy is ſufficient to impreſs the mind of the obſerver with a knowledge of that wonderful force eſtabliſhed between bodies, by which they mutually attract each other. All the phenomena in nature are dependent on this law, which the philoſopher contemplates with admiration, and the moſt uninformed inquirer cannot conſider without ſome degree of perplexity and aſtoniſhment.

The ſmalleſt bodies, as well as the immenſe maſſes that are compoſed by their union, are alike ſubject to this force, ſo neceſſary for the preſervation of the harmony of the univerſe: but its laws appear either to be eſſentially different, or differently modified, according to the maſs, bulk, or reſiſtance of the bodies acted on by its power. Without inquiring into its effects on the planetary * bodies, whoſe diſtances and motions it governs, let us obſerve what happens on the globe we inhabit, and endeavour to diſcover its laws of action.

Natural philoſophy teaches us, that two ſolid bodies of the ſame kind, when in contact, adhere together with ſo much the more force as the ſurfaces at which they touch are

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* The celebrated Bergman (de Attractionibus electivis) and others, as well as our author, from a wiſh to generalize, and in conſequence of a too ſuperficial view of the univerſal laws of attraction, have erroneouſly ſuppoſed that gravity, or the planetary attraction, might be ſo varied, when bodies became nearly contiguous, as to be modified or converted into the chemical affinity, or elective attraction obſerved between the minute parts of bodies. See Newtoni, Prin. I. § 13. T.

more poliſhed and extended. Thus two planes of glaſs, or two ſections of a metallic ſphere ſlipped upon each other with preſſure, become united, and often require a very conſiderable effort to ſeparate them. This effect is ſtill more ſtriking between two drops of a like fluid, ſuch as water, oil, or mercury. Placed at a certain diſtance from each other, upon an uniform ſurface, we ſee them mutually attract, move towards* each other, and unite into one ſingle globule. This force gives birth to all the phenomena obſerved in chemiſtry; and it is therefore of the higheſt importance to ſtudy with care, all the laws and circumſtances that accompany it.

The greater number of chemiſts have denominated this force affinity, or relation, becauſe it has been thought that it depended on an analogy or conformity of principles in the bodies between which it exiſts. Bergman has called it attraction, though its effects are very different from the planetary attraction obſerved by Newton; of which, however, it appears to be only a modification‖, as we ſhall hereafter ſee. This affinity may take place between bodies of the ſame, or of different natures. Let us obſerve it under theſe reſpective points of view.

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* I am perſuaded the ingenious author has drawn this concluſion without making the experiment. Drops of water, or other fluids, are ſo far from moving towards each other at any ſenſible diſtance, that according to the law followed by all bodies not nearly in contact, they repel each other. Hence during rain, the drops may be ſeen rolling along the ſurface of water in all directions, and the effect is ſtill more conſiderable in ſpirit of wine. T.

§ 1. Concerning the affinity that takes place between bodies of the ſame kind, or the affinity of aggregation.

When two bodies of the ſame nature, as for example, two globules of mercury placed at a certain diſtance from each other, tend by virtue of this force to unite, and the union is ſuffered to take place, a ſphere of greater magnitude, but of entirely the ſame nature, is formed. This force, therefore, produces no change, except in the phyſical, or obviouſly apparent qualities of bodies. It joins together parts of the ſame kind, which before were ſeparate; augments the bulk or magnitude by confounding the maſſes, and forms one ſimple body out of ſeveral. It is named the affinity of aggregation, to diſtinguiſh it from that between bodies of different natures. It produces an aggregate, in which, though the phyſical properties are changed, the chemical qualities are not ſenſibly altered. The aggregate is nothing more than a coherent body, whoſe molecules are united by the force of aggregation. It muſt be diſtinguiſhed from the maſs called a heap, which, though conſiſting of parts of the ſame nature, has not coherence throughout; as well as from a mixture which is taken to denote an incoherent maſs of diſſimilar particles. An example will illuſtrate this. Flowers of ſulphur, or ſulphur in powder, whoſe parts have no adheſion, but may be ſeparated by the ſmalleſt efforts, conſtitute a heap, on the parts of which, relatively conſidered, the affinity of aggregation does not act. If this be mixed with another heap, as of nitre in powder, a mixture by confuſion will be had. But if by the help of fuſion, the power of aggregation be cauſed to act, then the molecules, or integrant parts, brought towards each other during their liquefaction, unite and adhere together in ſuch a manner, as, that when cooled, they form a ſingle maſs or ſolid, which is a true aggregate.

‖ See the note on page 43.

The force or affinity of aggregation has different degrees, meaſurable by the effort or power neceſſary to be employed in ſeparating the integrant parts. We may diſtinguiſh four kinds of aggregates, under which all bodies in nature may be compriſed.

1. The hard or ſolid aggregate, in which the force that unites the integrant parts is very conſiderable, and which cannot be deſtroyed, but by ſome very violent re-action.

There are many degrees of aggregation under this claſs, from the hardneſs of the precious ſtones or rock chryſtal, to the ſoftneſs of the moſt yielding wood. Its character is to form a maſs, whoſe different parts cannot be ſenſibly moved amongſt each other, without breaking or ſeparation.

2. The ſoft aggregate is that, whoſe parts, tho' coherent, may nevertheleſs be ſlided upon each other by a ſmall force, ſo as to change their reſpective ſituation. The force that unites the parts of a ſoft body, is leſs than in ſuch as are hard; and leſs re-action is neceſſary to deſtroy it.

3. The fluid aggregate. Its integrant parts are ſo ſlightly united together, that the ſmalleſt effort is not only ſufficient to cauſe them to ſlide, or change ſituation amongſt, but alſo to ſeparate them from, each other.

4. Laſtly, the aeriform aggregate, whoſe integrant parts are too ſmall to be perceived, and in which the affinity of aggregation is the leaſt poſſible. The air of the atmoſphere furniſhes an example.*

Theſe four kinds of aggregate are no more, properly ſpeaking, than degrees of the ſame force, which it is nevertheleſs of great conſequence to diſtinguiſh with care, becauſe their ſtate and diverſity have a ſingular influence on chemical phenomena. This is proved in a very ſatisfactory manner, from the conſideration that many bodies are capable of being ſucceſſively put into each of theſe four ſtates. Water in the form of ice is a ſolid aggregate. Its hardneſs is the greater in proportion as its temperature is lower; when expoſed to the temperature of 32° Fahrenheit, it aſſumes a kind of ſoftneſs † before it paſſes to a ſtate of fluidity. This laſt mentioned ſtate is well known in all climates; and philoſophers have computed its force of expanſion when in the ſtate of vapor, or in the aeriform aggregation.

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* The aeriform aggregate is here erroneouſly defined or deſcribed. It is that whoſe denſity is not ſufficiently great, to afford obvious indications of its preſence, and in which the affinity of aggregation is negative, cauſing the integrant parts to repel each other. T.

In proportion as we advance in the knowledge of the laws of affinity, we ſhall perceive ſtill more the neceſſity of diſtinguiſhing and attending to theſe four kinds of aggregation. This is more particularly neceſſary in comparing the force of aggregation with the ſecond kind of affinity next to be examined.

As theſe two forces, which ſeem to depend on the ſame cauſe or principle, are nevertheleſs always oppoſed to each other in chemical phenomena, ſo that it may even be inferred from the facts we ſhall exhibit, that they are in the inverſe ratio of each other, ‡ it is neceſſary when the chemiſt wiſhes to cauſe the one to act, that he ſhould diminiſh the other, or reduce it to nothing. Now the attractive force we are ſpeaking of, is almoſt always that which he has occaſion to diminiſh, and it is likewiſe modifiable at pleaſure, by means in the power of the artiſt.

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† Quere? T.

To deſtroy or diminiſh the affinity of aggregation, nothing more is required, than to oppoſe to the coheſion of the parts of the aggregate, an external force more than equal to that which retains them together, which conſequently muſt be greater or leſs, in proportion to that adheſion. This is the leading principle in the preparatory operations, whoſe ſole purpoſe* is to deſtroy the affinity of aggregation: pulverization, grinding, filing, raſping, cutting, are operations that oppoſe the coherence of ſolids, and ſerve to ſeparate their parts. Filtration and evaporation produce nearly the ſame effect on fluids. The ſoftening and fuſion of bodies by heat, anſwer the ſame intention. Theſe operations, whoſe detail belongs to the practical part of chemiſtry, are only mentioned here to ſhew the connection they have with the theory.

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‡ This oppoſition of the affinities of aggregation and combination, muſt reſt intirely on the reaſoning of the author in the following pages. To me it ſeems neither fairly deduced nor probable in itſelf. A variety of important circumſtances, ſome of which are unknown, are included in this, and almoſt every other queſtion, concerning the affinities. They cannot here be entered into; but the preſent may perhaps be decided, by anſwering the following. Are there not many operations in which an increaſe of temperature at the ſame time weakens both the powers of aggregation and combination, and the contrary? If this were not the caſe, could any ſeparation be made by mere heat, without an intermedium? And if heat be matter, and be the intermedium in ſuch caſes, the affinity of aggregation, as it is called, is out of the queſtion. T.

* The purpoſe is to increaſe the ſurfaces, that the mutual action of bodies on each other being carried on at the ſame time among a great number of parts, may be ſooner finiſhed, and the intended proceſs completed. The affinity of aggre-

As art is poſſeſſed of numberleſs means of oppoſing the force of aggregation, ſo likewiſe it affords others for reſtoring, and cauſing it to act again with all its energy. All its manipulations for this purpoſe conſiſt in placing the bodies, whoſe aggregation it is propoſed to reſtore, in a ſtate of diviſion and fluidity, ſo that the particles of theſe bodies may be at liberty to obey the power of attraction, by applying to each other thoſe of their ſurfaces which are beſt adapted to unite; and the regular figure and coheſion often equal, and ſometimes even ſurpaſs, thoſe of natural bodies of the ſame kind. On this occaſion we muſt remark, that all aggregate

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aggregation impedes combination in no other way than by covering the internal parts. A lump of ſugar is ſlower in diſſolving, if put into water, than the ſame quantity in powder, becauſe in the former caſe the external parts muſt be diſſolved and removed, before the internal parts can be acted on. T.

gate bodies may be divided into two claſſes, namely, regular or irregular. Nature has given to every body the property of preſenting itſelf under one or other of theſe two ſtates; art, ever emulous, and often the rival of nature, can at pleaſure produce either. All bodies capable of paſſing through the different ſtates of aggregation before enumerated, and more eſpecially ſalts and metals, may, according to the management of the artiſt, in their paſſage from fluidity to ſolidity, appear in the ſhape of an irregular maſs, or in that of a body with regular facets, which is called a cryſtal. Nothing more is neceſſary to produce the former ſtate, than to keep the particles whilſt fluid, whether by heat or by water, very near each other, and to cauſe the liquefaction ſuddenly to ceaſe, ſo that coming into contact all at once, they may unite into an irregular maſs. But, on the contrary, cryſtallization requires that the parts of the bodies, in which it is to be produced, ſhould be kept ſufficiently diſtant from each other, that they may be as it were in equilibrium ſome time before they unite, and may mutually preſent to each other the ſurfaces that beſt agree with each other. After theſe details, it is clear that cryſtallization is entirely the conſequence of the affinity of aggregation. It is in this point of view that we have here conſidered it; and ſhall reſerve our future obſervations on the ſubject, to the other parts of this work.

§ 3. Concerning the Affinity between two Bodies of different Natures, or the Affinity of Compoſition.

When two bodies of different kinds have a tendency to unite, they then combine by virtue of a force different from that we have hitherto ſpoken of, and which is named the affinity of compoſition or combination. This kind of affinity, more neceſſary to be underſtood than the former, takes place in all the operations of chemiſtry, none of which can be explained without it. This principle was known in the earlieſt times, but it was not attended to with ſufficient care, till experience had ſhewn that its influence on the practice is equal to that on the theory of the ſcience we are treating of. It is this doctrine that muſt guide the practitioner in the reſearches neceſſary for the advancement of chemiſtry, and muſt be conſulted by the philoſopher who collects and compares the facts. It is the compaſs by which both muſt ſteer; and it may be truly affirmed, that he who is intimately acquainted with the affinities, knows every thing that the moſt ſublime chemiſtry has to offer.

Well convinced of this truth, we ſhall endeavour firſt to collect with fidelity all the facts that relate to them, and afterwards to explain the hypotheſes that have been invented, reſpecting their cauſe.

Obſervation, the parent of chemiſtry, as well as of every experimental ſcience, has ſhewn, that the affinity of compoſition preſents conſtant and invariable phenomena, which may be regarded as eſtabliſhed laws, obvious to all but thoſe who are unacquainted with the method of ſtudying nature. Theſe laws, founded on a great number of well eſtabliſhed facts, may be reduced to the eight following.

Firſt Law of the Affinity of Compoſition.

The affinity of compoſition does not take place but between bodies of different natures.

This firſt law is invariable, and ſubject to no kind of exception. In order that two bodies may combine, and form a compound, it is a neceſſary condition that they ſhould be of different kinds. In fact, if two bodies of the ſame nature be united, the reſult will be nothing but an aggregate, whoſe maſs and magnitude only will be augmented without the loſs of any of its eſſential properties, and the union will be preſerved by the affinity of aggregation, as has been already ſhewn. Thus two pieces of wax, reſin, or ſulphur, are united by heat. The difference between the affinities of aggregation and of compoſition may hence be eaſily conceived.

This law is ſo true and ſo conſtant, that the affinity of combination is never ſo powerful, as when the bodies, between which it is exerted, are of the moſt different kinds. Thus it is that acids, whoſe properties are ſo oppoſite to thoſe of alkalies, combine and form the moſt perfect compounds with them. The ſame oppoſition of properties is obſerved between alkali and ſulphur, alkali and water, acids and metals, ſpirit of wine and water, &c. all which have an exceeding ſtrong tendency to combine with each other, and to form the moſt perfect compounds, though their nature is totally different.

It is ſtill more neceſſary to attend to this leading principle, of the affinity of compoſition, becauſe many chemiſts, with Stahl at their head, have endeavoured to prove, that bodies never entered into combination, but in conſequence of a certain agreement, or reſemblance of their properties; an opinion, which muſt of courſe be rejected, when the full extent of this law is underſtood. On peruſing the writings of the greateſt chemiſts on this ſubject, it is ſeen, that the reſemblances they endeavour to find between ſubſtances that have a great tendency to unite, are always very remote; and that by following the ſame method, it is poſſible to find others equally ſtrong between the moſt diſſimilar bodies. It is, however, not difficult to obſerve, that theſe great philoſophers were deſirous of rendering the theory of affinities more intelligible, by means of this explication; and thoſe who are aware of the extreme difficulty that attends the eſtabliſhment of theory, in any branch of human knowledge, will be ready to conſider their efforts with the gratitude to which they are entitled. Their works are of the higheſt utility, by the illuſtrative arrangement and connection of the facts they have brought together. But our firſt homage is due to truth, which compels us to avow our ignorance of the cauſe of this extenſive ſimilarity of facts which we offer as a law of nature, rather than to have recourſe to an analogy, which is contradicted by examining into the properties of bodies.

Second Law of the Affinity of Compoſition.

The Affinity of Compoſition does not take place, except between minute Bodies.

In order to conceive this law as it really exiſts, it is neceſſary to diſtinguiſh thoſe ſubjects concerning which the chemiſt reaſons, from others properly called phyſical. The latter are bodies, whoſe exterior properties, ſuch as maſs, bulk, ſurface and figure, may be ſubmitted to computation, and appreciated by the ſenſes. The natural philoſopher or mechanic is buſied in the conſideration of aggregates. Chemical ſubjects, on the contrary, are bodies that have loſt their aggregation, and conſequently no longer exhibit the phyſical properties of aggregates to the ſenſes. They are particles ſo ſubtle, that their figure and value cannot be known from meaſurement. Bodies do not obey the affinity of compoſition, till they have been reduced by the preparatory operations, to the requiſite degree of minuteneſs. It ſeems as if this property were confined in its operation to the infinitely ſmall particles, or ultimate molecules of bodies. Hence it appears, that the affinity of compoſition differs from the attraction ſubſiſting between large bodies. This difference is ſtill more ſtriking, when we conſider the oppoſition which is obſerved between the affinities of aggregation, and the affinities of compoſition. This oppoſition is ſo well eſtabliſhed, that I can venture to advance, as a chemical axiom, that the ſtronger the affinity of combination, the weaker the affinity of aggregation. Theſe two forces ſeem to be oppoſed to, and mutually to counteract each other. In fact, the affinity of aggregation oppoſes the combination of bodies, and therefore ſuch as have a ſtrong force of aggregation, have very little tendency to enter into combination; while ſubſtances, that have little or no aggregation, have, at the ſame time, a very ſtrong diſpoſition to combine with others. The various kinds of air, for example, are, among all bodies, thoſe which have the weakeſt power of aggregation, and are likewiſe thoſe which have the greateſt diſpoſition to unite with almoſt every other kind of body.

Laſtly, To eſtabliſh the leading principle, we ſhall not heſitate to conclude, that as there are many caſes, in which the affinity of aggregation counteracts the affinity of compoſition; as in all ſolid bodies, ſuch as metals, ſulphurs, lead, ſaline cryſtals, &c. which cannot be united to acids, alkalis or water in their ſtate of ſolidity; ſo there are likewiſe ſome caſes, in which the affinity of compoſition not only oppoſes, but even deſtroys the force of aggregation. It thus happens, when we bring together two fluids that have a great affinity to each other, and at the ſame time tend to take the aerial or vaporous form; as the cauſtic volatile alkali, and the marine acid, when each exhales a viſible fume, conſiſting of ſubſtance itſelf, whoſe aggregation is broken by the force of combination, and which approaches and comes into contact with the other neighbouring body. This phenomenon takes place when two glaſs veſſels are placed near each other, containing the fluids abovementioned. It is obſerved alſo between the volatile alkali, and the humid metallic ſalts. It often happens that theſe bodies, expoſed in covered veſſels ſeveral feet aſunder, tend in ſuch a manner to unite, that they eſcape in viſible vapours, whoſe direction carries them manifeſtly towards each other.

Third Law of the Affinity of Compoſition.

The affinity of compoſition can exert its action on more bodies than two.

This law of affinity is one of thoſe we are leaſt acquainted with, and has been hitherto but very imperfectly inquired into. Many affinities and combinations of two bodies are known. Fewer of three, and ſtill fewer of four bodies united by equal affinity have been noticed. The metals alone preſent ſuch combinations, and may be combined with two, three, or four. It is probable that combinations of more than four, as for example, ſix or eight bodies may exiſt; but art has hitherto thrown very little light on this ſubject. The cauſe of the ſlow progreſs of the ſtudy of this law, will be ſhewn when we come to treat of the eighth law. The affinity that may take place between many bodies is denoted by their number, by ſaying the affinity of two, three, four bodies, and ſo forth. The rapid advancement of modern chemiſtry, the multiplicity of reſearches that are purſued, and the ſcrupulous exactneſs of the preſent methods, give us reaſon to hope that theſe affinities, which are called complicated, will ſoon become better known.

Fourth Law of the Affinity of Compoſition.

In order that the affinity of compoſition may take place between two bodies, it is neceſſary that one of the two at leaſt ſhould be in a ſtate of fluidity.

This law has been long known to chemiſts, and is expreſſed by the following axiom, Corpora non agunt niſi ſoluta. The moſt connected and exact obſervations have ſhewn, that two ſolid ſubſtances cannot unite into combination with each other. Whence it happens, that bodies, which have the greateſt tendency to unite, cannot effect it, unleſs one of them be in the ſtate of fluid aggregation. The more fluid the bodies which the chemiſt is deſirous of combining are, the leſs aggregative force they have, and conſequently the more eaſily and intimately they may be united. It is for this reaſon, that no combination is more rapidly or more perfectly made, than when two aeriform bodies are brought into contact, as the marine acid air, and alkaline air.

Though two ſolid bodies can never combine, yet there are certain circumſtances in which dry ſubſtances reduced to fine powder act with ſufficient energy on each other, to unite and form a new compound. Thus I have obſerved, that the cauſtic fixed alkali unites when cold by ſimple trituration

tion with ſulphur, antimony, and kermes mineral, as I ſhall elſewhere deſcribe; but in this caſe, the extreme diviſion of the two bodies and the moiſture of the atmoſphere, attracted by the ſalt which ſoon deliquiates, are of ſingular advantage to the combination, and in fact bring it within the law we are treating of.

It is not always neceſſary that both the bodies we wiſh to combine ſhould be fluid, but only that one of them ſhould be ſo. During their union a phenomenon takes place, which chemiſts call diſſolution or ſolution. It is the attenuation, diviſion, and total diſappearance of the ſolid body placed in contact with the fluid. To underſtand the cauſe of this phenomenon, it is to be conſidered, that the affinity of combination which exiſts between two ſubſtances, the one fluid, and the other ſolid (as for example, the vitriolic acid and a piece of calcareous ſpar) is ſtronger than the affinity of aggregation that unites the particles of ſpar, and cauſes it to poſſeſs a ſolid form. Now, ſince by the third law this affinity cannot take place but between ſmall bodies, it becomes a neceſſary condition that the ſpar muſt be reduced into very ſmall particles by the loſs of its aggregation, before it can unite with the vitriolic acid, and form ſelenite. The ancient chemiſts in all ſolutions made a diſtinction between the ſolvent, and the body intended to be diſſolved; the former being the fluid, and the latter the ſolid. This diſtinction, which ſuppoſes in the fluid a force ſuperior to that exiſting in the ſolid aggregate, cannot be admitted by modern chemiſts, who obſerve with M. Gellert, that in ſolution the action is equal on both ſides, and that in the example here cited, the vitriolic acid would not deſtroy the aggregation of the ſpar, if this laſt did not tend to combine with the vitriolic acid with an equal force. The term ſolvent, at preſent applied to fluids, is therefore far from being chemical, and preſents to the mind the idea of a mechanical action; for which reaſon it would be better to reject it altogether. But as cuſtom has unfortunately prevailed, it becomes neceſſary to remember, that when one body is ſaid to diſſolve another, nothing more is intended to be expreſſed, than the ſtate of fluidity of the former; and that no greater activity is attributed to it than to the ſolid, which poſſeſſes exactly the ſame force.

The falſe idea that has till lately prevailed concerning ſolution, has doubtleſs ariſen from the mechanical theory of this operation of nature, which certain philoſophical chemiſts have invented. This theory, which is found in every page of Lemery, conſiſts in ſuppoſing the ſolvent an acid, for example, to be an aſſemblage of very acute points, and the body to be diſſolved as poſſeſſing an infinite number of pores, in which the points of the acid are received, which tear aſunder its parts, and by that means reduce it to ſuch a ſtate of diviſion, as to cauſe it to eſcape the ſight. It is ſufficient to exhibit the opinion; the more accurate and leſs hypothetical method of cultivating philoſophy, which is now univerſally adopted, will ſave us the trouble of confuting it.

Fifth Law of the Affinity of Compoſition.

When two or more bodies unite by the affinity of compoſition, their temperature changes at the inſtant of their union.

This phenomenon has appeared ſo conſtantly to attend every operation that art can perform, that we have thought proper to conſider it as one of the laws of the affinity of compoſition. The temperature of bodies during combination, may be altered by the production of either heat or cold. The latter takes place much oftener than the former; but as cold is produced in many ſynthetical operations, we have expreſſed this phenomenon, by the words "change of temperature."

It may be objected, that there are certain ſolutions or combinations ſlowly effected, in which no change appears. To this we anſwer, only by requeſting that they will plunge a very ſenſible thermometer in theſe ſolutions, and they will be convinced that a change of temperature takes place, which is almoſt always warmer than that of the atmoſphere.

This phenomenon ſeems likewiſe to depend on the change of the aggregation of the ſubſtances that become combined, in their paſſage from ſolidity to fluidity, according to the obſervation of Beaumé, of which we ſhall elſewhere ſpeak. But as this change of aggregation is a conſequence of the action of the affinity of combination, it is evident that this laſt affinity is the cauſe of the change of temperature.

M. Macquer was of opinion, that the variations in the temperature of bodies that enter into combination, depended on the motion the particles are put into; but if this explanation be admitted as ſufficiently indicating the cauſe of heat in caſes in which it is obſerved, it certainly does not explain other caſes, wherein cold is produced. Some modern chemiſts, and in particular Scheele and Bergman, are of opinion, that heat, which they eſteem as a peculiar ſubſtance, is greatly concerned in chemical combinations, producing cold when abſorbed, or heat when diſengaged. Though this theory explains very well the changes of temperature that takes place when bodies unite, it is nevertheleſs ſubject to very great difficulties; the chief of which, as we ſhall prove when we come to ſpeak of fire, are founded on the conſideration, that the exiſtence of heat, as a peculiar ſubſtance, is by no means demonſtrated.

Sixth Law of the Affinity of Compoſition.

Two or more bodies, united by the affinity of compoſition, form a ſubſtance, whoſe properties are very different from thoſe of any one of the bodies before their combination.

This law in particular requires to be well proved, becauſe many celebrated chemiſts of the preſent age have entertained notions reſpecting compounds, which by no means agree with the greater number of facts, and are directly oppoſite to what we here offer, as one of the principal and moſt remarkable of the phenomena attending the affinity of compoſition.

Stahl and his followers, whoſe abilities in other reſpects have been of ſuch important ſervice to chemiſtry, have affirmed, that compounds always partake of the properties of the bodies that enter into their compoſition; and that their properties are intermediate between thoſe of their principles. They have even carried this notion ſo far, as to imagine that it was poſſible to conjecture, from the properties of a compound, the nature of the bodies that compoſe it. From conſiderations of this kind it was, that Stahl pronounced ſalts to be compoſed of earth and water, becauſe he thought he obſerved in all ſalts, properties intermediate between theſe two ſubſtances. As we propoſe to diſcuſs this doctrine when we arrive at the part of our work that treats of ſalts, we ſhall make no obſervations on this example in this place, but ſhall content ourſelves with obſerving that the chemiſts, who have followed Stahl in this opinion, have not had better ſucceſs than himſelf in their proofs; and that the intermediate or mean properties which they have pretended to diſcover in compounds, have ſeldom any but the moſt remote agreement with thoſe of the ſubſtances that conſtitute the combination. This obſervation we ſhall eſtabliſh from the conſideration of the very inſtances that are urged by Stahl himſelf. And we cannot here avoid remarking the difficulty which that author appears to have met with in eſtabliſhing this opinion in his writings, and the embarraſſment which prevails in his explanations. Theſe conſiderations engaged M. Bouquet and myſelf to examine this theory with attention, and induced us to adopt another directly oppoſite to it.

In reality, nothing more will be neceſſary to prove the exiſtence of the law concerning which we are now treating, than to point out inſtances of compounds whoſe properties are entirely new, and have no kind of relation to thoſe of their component parts. The hiſtory of every chemical combination tends to ſupport our poſition, and there is not a ſingle fact which will not furniſh matter for its proof. We ſhall therefore ſelect a few ſtriking inſtances in well known combinations, from which it will follow: 1. That bodies, which enter into combination, loſe the properties they before poſſeſſed. 2. That they acquire new properties totally different.

Let us fix, then, in order to proceed with method, upon ſuch properties, as if varied, will affect the ſenſes very conſiderably in conſequence of ſuch variation. The taſte is often very conſiderable in two ſimple bodies, and when they are combined, they have a very faint or feeble taſte when compared with that before poſſeſſed by either. Vitriolated tartar, which is produced from the union of two ſtrong cauſtics, oil of vitriol and pure ſalt of tartar, has only a bitteriſh taſte, which can by no means be regarded as intermediate between the two cauſtic ſalts. On the contrary, two bodies that have little or no taſte may acquire a very pungent one by their union. Mercury and the marine acid, given ſeparately in a doſe of a few grains in a glaſs of water, are not capable of producing any noxious effect on the animal economy; while the ſame doſe of corroſive ſublimate formed by the union of theſe ſubſtances, and adminiſtered in the ſame vehicle, is one of the moſt violent poiſons, and of a moſt corroſive taſte.

The affinity of compoſition has a ſingular influence on the form. It often happens, that two matters, that are not ſuſceptible of cryſtallization alone, aſſume a regular form when they are united, as is the caſe with the marine acid air, and alkaline air, which in the inſtant of their union conſtitute cryſtals of ſal-ammoniac. In other caſes, the form is ſimply changed and modified; as in the union of certain neutral ſalts with each other, and in metallic alloys, which exhibit, according to Abbé Mongez, cryſtallizations ſomewhat differing from thoſe of the metals in a ſtate of purity. Laſtly, bodies very ſuſceptible of cryſtallization alone, loſe this property when united with other bodies; as metals united with air, and ſome of them when united with acids.

The ſame obſervations, in proof of the law we offer, may be made with regard to conſiſtence. It is ſeldom the ſame in a compound, as in the principles that compoſe it. Thus it is found that two fluids, united with each other, ſuddenly produce a ſolid, as is ſeen in oil of tartar added to oil of vitriol; and that from the union of two ſolids there frequently reſults a fluid, as in neutral ſalts combined with ice, and in the mixture of an amalgam of lead with an amalgam of biſmuth.

The colour is frequently altered in combination. Sometimes it diſappears, as when the coloured marine acid is added to a metal, the ſolution is tranſparent. Very often two bodies aſſume a deeper colour than before, in conſequence of their union; as when iron or copper are diſſolved in moſt acids, or lead, mercury, and moſt of the metals united to pure air, and in the ſtate of metallic calces.

It is frequently found that two bodies of very pungent ſmell form, by uniting, a ſubſtance without ſmell; as the marine acid air and alkaline air already mentioned, both which have a ſuffocating ſmell, but in their union form ſal-ammoniac, which has ſcarcely any ſmell. Again, from inodorous bodies a compound maſs ariſes, whoſe ſmell is ſtrong; as is obſerved when ſulphur and fixed alkali form the very fœtid ſubſtance called liver of ſulphur.

We may proceed to the conſideration of fuſibility. Two very infuſible ſubſtances may become very fuſible when united. Combinations of metals will melt with the heat of boiling water, and combinations of earths will flow into glaſs; but the ſimple ſubſtances themſelves are much leſs fuſible.

The foregoing facts are far from being the only ones which might be urged in ſupport of this law. There are many other that will offer in the courſe of chemical reading, which it will not be at all difficult to apply.

Seventh Law of the Affinity of Compoſition.

The affinity of compoſition is meaſured by the difficulty of deſtroying the combination formed between two or more bodies.

Chemiſts are acquainted with methods of ſeparating bodies in combination with each other; but theſe methods are more or leſs eaſy, and differ in their degree of complication or ſimplicity. In obſerving the appearances that take place in theſe proceſſes, it is conſtantly ſeen that the more perfect the compound, the more difficult it is to ſeparate the principles, and deſtroy the compoſition. The degree of difficulty experienced in making this ſeparation, may therefore ſerve to ſhew the adherence, or affinity, that exiſts between bodies reſpectively.

We inſiſt the more ſtrongly on this law, becauſe it is eaſy for beginners to miſtake in eſtimating the difference of affinity that obtains among the ſeveral bodies they combine together. The rapidity with which certain bodies unite, may naturally produce a concluſion that the adheſion between them is very ſtrong. Long experience, however, has ſhewn that this rapidity, ſo far from indicating the more perfect combinations, rather ſhews a weak adheſion, and produces only a very imperfect compound. In order, therefore, to fix with exactneſs the degree of affinity with which bodies combine and remain united, we muſt have recourſe to the meaſure of the difficulty experienced in ſeparating them, or deſtroying their union. The examination of the eighth and laſt law will clear up this matter.

Eighth Law of the Affinity of Compoſition.

All bodies have not the ſame force of affinity with reſpect to each other; and it is poſſible from obſervation, to determine the degree of the force exiſting between different bodies.

All bodies have not an equal tendency to combine with each other. There are ſome which abſolutely refuſe to unite, or at leaſt cannot be directly united by art, as iron and mercury, water and oil, &c.; though it cannot be thence inferred that there is no affinity between them; other ſubſtances unite with great difficulty, and after a very long time.

But the moſt important circumſtance in the variety of affinity is, that as this force is not equal amongſt all bodies, it is practicable from the knowledge and application of this phenomenon, immediately to effect the ſeparation of two bodies, whoſe union forms a compound. It is even certain, that the moſt eſſential part of the art of chemiſtry conſiſts in producing ſuch decompoſitions, by means of which, it works a kind of miracle in the eyes of ſuch as are unacquainted with them. To explain this, let us ſuppoſe two bodies to adhere together, with a force denoted by the number four, as for example, an acid and a metal; and let a third body be preſented, which has an affinity to the acid equal to five or ſix, as for example, an alkali. What will be the conſequence? The alkali, which tends to unite with the acid, by virtue of a force ſuperior to that which joins the ſame acid to the metal, muſt ſeparate the latter, in order to ſeize the acid. As this in fact takes place, the metal is ſeparated, and a new combination is formed between the acid and the alkali. This decompoſition is denominated precipitation, becauſe the matter ſeparated commonly falls to the bottom of the fluid.

The matter that falls to the bottom is called a precipitate, and the ſubſtance added is called the precipitant. Precipitates may be diſtinguiſhed into four kinds. The true precipitate is formed, when one of the principles, ſuch as it exiſted in the compound, is ſeparated, and falls down. Thus when ſelenite, formed by the combination of the vitriolic acid and quick-lime, is decompoſed by the addition of the pure fixed vegetable alkali, which has a greater affinity with the acid, the lime is ſeparated, and, falling to the bottom, conſtitutes a true precipitate. There is a falſe precipitate obtained, when the new combination, formed between the precipitant or ſubſtance added and one of the principles of the compound, falls to the bottom by reaſon of its inſolubility, and the ſeparated matter remains in ſolution. Thus in decompoſing the nitrous ſolution of mercury by the marine acid, with which that metallic ſubſtance has more affinity than with the former acid, the new combination of mercury and marine acid falls to the bottom of the veſſel, forming a falſe precipitate, above which the nitrous acid remains diſſolved in the water. This difference depends only, as we ſhall ſee elſewhere, on the difference of ſolubility of the matters.

It may eaſily be ſeen, that the erroneous denomination of this laſt example tends to miſlead beginners. It is certain that thoſe, who gave the name of precipitate to the ſubſtance ſeparated from the compound by the precipitant, ought not to have applied it alſo to the new combination produced in the latter caſe. But even ſuppoſing that the name precipitate were confined to the matter ſeparated by the precipitant, it would ſtill be productive of error, becauſe there are many caſes in which the ſeparated matter, ſo far from falling to the bottom, riſes and is volatilized. This happens when the combination of marine acid and volatile alkali is decompoſed by quick-lime, which has a greater affinity to the acid than the volatile alkali has; the latter flies off in vapour, and no precipitate is found in the mixture. To avoid this confuſion of nomenclature, it would be proper to ſubſtitute the name of decompoſition, inſtead of that of precipitation: but as the cuſtom has prevailed, we preſerve the uſual names, firſt pointing out the errors to which they may give riſe.

It is ſufficiently clear, that a liquid muſt be preſent in the operations that afford the precipitates we have ſpoken of. In this caſe the precipitation is ſaid to be effected in the humid or moiſt way, in order to diſtinguiſh it from that which is made in the dry way, or by fire, and which is effected either by fuſion or diſtillation; operations that will be explained at length in the following part of this work.

Modern chemiſts have likewiſe diſtinguiſhed with much more propriety two other kinds of precipitates. Theſe are pure and impure precipitates. The firſt comprehend all bodies which, after having been ſeparated from the compounds of which they were before a part, regain all their former properties, and appear to have ſuffered no alteration, either in conſequence of their having entered into a combination, or of their ſubſequent ſeparation. This number of this kind of precipitates is very conſiderable, though that of the impure kind is ſtill greater.

That a precipitate may be very pure, it is neceſſary, not only that it ſhall have ſuffered no change in becoming part of a compound, but likewiſe that it ſhall have no affinity with the precipitant. For example, when ſpirit of wine is poured on a ſolution of vitriolated tartar in water, the ſpirit of wine, which has more affinity with the water than it has with the ſalt, ſeparates the latter; and the vitriolated tartar falls down in a ſtate of purity, becauſe it has ſuffered no alteration from the water it was combined with, nor with the ſpirit with which it cannot unite. But if two bodies are mutually altered in their union, as is the caſe when metals are combined with acids, then the third body employed to ſeparate them, as for example an alkali, will precipitate the metal in a ſtate widely different from that which is natural to it, and by that means exhibits an impure precipitate. The ſame thing happens, if the precipitant has any tendency to unite with the precipitate; as in the example already cited of a metallic ſolution decompoſed by an alkali, a part of this laſt ſalt may combine with the metal, and render it impure.

pure. Theſe two cauſes of the impurity of precipitates are almoſt always united; whence it happens, that one of the moſt certain methods of diſcovering a falſe precipitate, excluſive of the abſence of the eſſential properties it ought to poſſeſs, is to add a much greater quantity of the precipitant than is neceſſary to deſtroy the combination, and the exceſs, by combining with and diſſolving the precipitate, will cauſe it to diſappear. By pouring the volatile alkali on a ſolution of copper in the nitrous acid, the copper is precipitated in the form of flocks of a light blue colour. The colour of this precipitate, far from reſembling the metallic brilliancy of copper, immediately ſhews it to be an impure precipitate. This is ſtill more confirmed by the addition of more volatile alkali. This ſalt diſſolves again the blue precipitate, the liquor gradually reſumes its tranſparency, and aſſumes a beautiful blue colour, which indicates the combination of the calx of copper with the volatile alkali.

The exact knowledge of theſe impure precipitates, which preſent themſelves much more frequently than the pure, is due to the reſearches of M. Bayen on the decompoſition of mercurial ſolutions by alkalis, and the ſtate of the precipitates obtained in theſe operations.

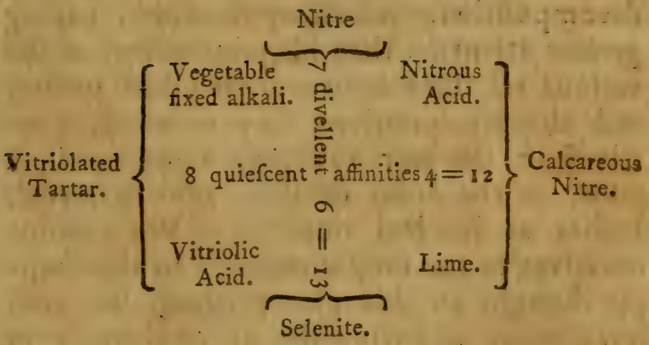
After the foregoing explanations, it will not be at all difficult to underſtand the theory of decompoſitions, as effected by the addition of a third body to a combination of two. As there ſeems to be a kind of choice or preference between one of the principles of the compound, and the ſubſtance added, in conſequence whereof the ſeparation of the two firſt takes place, Bergman has adopted a name very well calculated to afford an exact notion of the fact: he calls this force elective attraction.

Beginners will not find the ſame facility in underſtanding what paſſes in the more complicated phenomena called by chemiſts double affinities, and by Bergman double elective attraction. It often happens, that a combination of two bodies cannot be deſtroyed by a third or a fourth body ſeparately, though if a compound of the two laſt were preſented to the former, a mutual decompoſition would take place. An example will render this clear. Vitriolated tartar, or the combination of the vitriolic acid with fixed vegetable alkali, cannot be decompoſed either by the cold nitrous acid, or by lime, if preſented ſingly. But if to a ſolution of vitriolated tartar be added the neutral ſalt formed by the union of the nitrous acid and lime, the two combinations are mutually decompoſed; the nitrous acid ſeizes the vegetable alkali, and forms nitre, while the vitriolic acid, uniting with the lime, forms ſelenite;

which, being much leſs ſoluble than the nitre, falls to the bottom. The explanation of this remarkable phenomenon is as follows. The vitriolic acid, united with the vegetable fixed alkali, cannot be decompoſed by the nitrous acid, nor by lime; becauſe its affinity with the alkali is greater than that of the nitrous acid or lime, either to itſelf, or to the alkali: But when the compound of nitrous acid and lime is preſented, the tendency of this laſt acid to the alkali of the vitriolated tartar, together with that of the vitriolic acid to the lime, is greater than the attractions that lead to preſerve the original forms. To render this ſtill clearer, let us aſſume numbers to expreſs the forces. Suppoſe the vitriolic acid to adhere to the alkali, with a force denoted by 8; the nitrous acid tends to unite with the alkali with a leſs force, which therefore we may call 7; and therefore cannot ſingly effect the decompoſition. Again, if on the other ſide, the tendency of the lime to unite with the vitriolic acid be aſſumed for the ſame reaſon to be 6, no decompoſition will take place by its being ſingly preſented. But if nitrated lime be added to vitriolated tartar, there will be an oppoſition of attractions to each other. The firſt attraction 8, tending to preſerve the original form of the vitriolated tartar, will be oppoſed by the two attractions 7 and 6 equal to 13, tending to decompoſe it; and therefore, if the attraction tending to preſerve the form of the other compound, nitrous acid and lime, be leſs than 5, or the difference of 8 and 13, a double decompoſition will follow. So that if this laſt attraction be 4, the principles will arrange themſelves ſo as to ſatisfy the greater attraction of 7 added to 6, inſtead of the leſs of 8 added to 4. The combinations will therefore be nitrous acid with alkali, and vitriolic acid with lime.

In double affinities there are therefore two kinds of affinities, which it is neceſſary to diſtinguiſh. 1. That by virtue of which the principles of each compound adhere to each other. Mr. Kirwan calls this firſt force the ſum of the quieſcent affinities, becauſe it tends to preſerve the union of the principles in their original form. 2. That by virtue of which, the four principles change their order, and form new combinations. Mr. Kirwan calls this ſecond force the ſum of the divellent affinities, becauſe it is capable of deſtroying the effect of the former. By the help of this uſeful diſtinction, we may very eaſily ſhew what happens in the decompoſition and new combinations by double affinity, by forming a table after the manner of Bergman. For this purpoſe the two compounds, that mutually decompoſe each other, are to be placed between two braces oppoſite each other, ſo that the acids may be oppoſed to the baſes they exchange, and by adding together the numbers expreſſing the force of affinity the four bodies have for each other, the two horizontal numbers will give the ſum of the quieſcent affinities, while the two vertical numbers will exhibit the divellent affinities by which they are oppoſed. If the ſum of the latter exceeds that of the former, a double decompoſition and combination will follow. By applying the method to the preceding example, its utility and preciſion will be eaſily ſeen.

EXAMPLE.



I have explained ten examples of double decompoſitions that take place in mixing neutral ſalts, in my Memoires et Obſervations de Chimie, vol. 1. p. 308 and 438.

Chemiſts have not, till very lately, attended to the double affinities; and the inſtances wherein they take place are far from being all known. They, who employ themſelves in chemical reſearches, will continually obſerve this kind of decompoſition in circumſtances where no ſuch event has been ſuſpected. Many occaſions will preſent themſelves in the hiſtory of ſaline matters, in which we ſhall obſerve theſe affinities, as lately diſcovered by Bergman, Cornette, and ourſelves.

We cannot quit the explanation of this tenth and laſt law of affinity, without taking notice of the ingenious method, firſt contrived by a French chemiſt, to exhibit at one view, the leading phenomena of chemical decompoſition. Geoffroy the elder, paying greater attention than his predeceſſors to the various relations between chemical bodies, and the precipitations they occaſion, contrived in the year 1718, to repreſent in a table, in the order of their affinities, ſuch bodies as he had obſerved. We confine ourſelves to the ſimple mention of this happy thought in this place, which we ſhall have many opportunities of explaining in the courſe of the preſent work. Geoffroy offered his table to the public, as an eſſay to which he foreſaw it would be neceſſary to make great additions and alterations. Many chemiſts have adopted and extended his plan. Rouelle the elder made ſome corrections in his table, and added ſeveral columns. M. de Limbourg, a phyſician at Spa, in an excellent diſſertation, which gained, in conjunction with M. Sage of Geneva, the prize propoſed in 1758 by the academy of Rouen, has conſtructed a table of ſtill greater extent. Gellert, in his Metallurgic Chemiſtry, has alſo given a new one. But no one has advanced this part of chemiſtry more than M. Bergman, profeſſor of chemiſtry at Upſal. This celebrated chemiſt has made a diſtinction between the affinities that take place in the dry and in the humid way. He has given two very large tables, in which he ſhews the affinities between moſt bodies in nature. We are likewiſe indebted to the ſame philoſopher for a very ingenious table, in which he has found means, by a peculiar diſpoſition of the chemical characters, to preſent a view of the phenomena of double affinities; of which an example has juſt been given.

After having thus exhibited the principal phenomena of the affinity of combination, and eſtabliſhed the laws by which this force appears to be governed, we ſhall proceed to take notice of certain caſes in which theſe laws ſeem to be ſubject to variation. We ſhall not here enter into a detail of the facts on which this aſſertion is grounded, becauſe it is our intention to remark them carefully wherever they occur. We ſhall, therefore, only obſerve, that the apparent inconſtancy of the laws of affinity depends ſolely on certain modifying circumſtances; as the quantity of matter, the temperature of the atmoſphere, motion or reſt, ſolution by water or by fire, that is, by the humid or dry way, the particular ſtate of aggregation, &c. Bergman has conſidered all theſe circumſtances with ſingular care and attention, and has explained the various apparent changes they are capable of producing in the laws of affinity. And from the whole of the facts which he has collected on this ſubject, he has concluded that theſe variations ought not to be regarded as exceptions, and are by no means ſufficient to weaken the evidence on which the doctrine of affinities is founded.

This ſhews the opinion which ought to be entertained of two other kinds of affinity admitted by certain authors. The one is the affinity of intermedium, and the other the reciprocal affinity. By the firſt, they underſtand that which cauſes a body in combination with another to unite with a third, though it would not have united with this laſt, if it had not previouſly been combined with the former. Oil, for example, will not unite with water; but where the oil is combined with a ſalt, a ſoap is produced ſoluble in water, by the medium of the ſaline matter. It is not, however, the ſalt that renders the ſoap ſoluble, becauſe it does not exiſt in the combination with all its ſaline properties; but it is to the new properties of the compound ſoap, that its ſolubility in water is to be referred. This phenomenon is intirely dependent on the eighth law of affinity, which declares, that compounds poſſeſs properties intirely new and different from thoſe of their component parts.

The reciprocal affinity takes place when a compound of two bodies is decompoſed by a third, and the ſeparated principle is capable of decompoſing the new combination in its turn; ſo that there ſeems to be a ſort of reciprocity in the effects. So, for example, it is found that the vitriolic acid has a greater affinity with the fixed alkali than the nitrous acid has, and that it decompoſes the combination of this alkali with the latter acid. Neverthleſs, the nitrous acid can in its turn ſeparate the vitriolic acid from the alkali, ſince it is certain, that by heating vitriolated tartar with nitrous acid, nitre is again formed. This kind of affinity admitted by M. Beaumé, is to be attributed ſolely to the circumſtances that produce a change in the forces. For it is in fact neceſſary that the nitrous acid ſhould be hot, to decompoſe vitriolated tartar, and the nitre formed in this operation is again decompoſed by the vitriolic acid, when the mixture becomes cold. The fuming or phlogiſticated nitrous acid decompoſes vitriolated tartar in the cold; fuming ſpirit of ſalt effects the ſame decompoſition according to the obſervation of M.

Cornette; but Bergman has with great reaſon obſerved, that the fuming acids, which he calls phlogiſticated, have other affinities than the ſame acids ſimple, pure, or dephlogiſticated.

In every caſe of this kind, the order of the affinities is changed and modified by particular circumſtances. The other facts whereon Beaumé founds his proof of the reciprocity of affinities, as the decompoſition of ſal-ammoniac by chalk, and of the calcareous marine ſalt by concrete volatile alkali, belong to the double affinities, as we ſhall ſhew when we come to ſpeak of theſe ſalts.

Nothing remains at preſent to conclude our diſcourſe on the affinities, but to exhibit the opinions of ſome philoſophers on the cauſe of this force.

Thoſe philoſophers, who firſt attended to the ſubject, attributed it either to the ſimilar figure of the elementary molecules, or the phyſical configuration of the parts; or laſtly, to a certain occult relation of their intimate compoſition. Theſe early notions are neceſſarily connected with the mechanical explications that embarraſſed the ſcience of natural philoſophy in its infancy.

The greater number of ſuch modern philoſophers, as have endeavoured to explain the cauſe of affinity, have obſerved an analogy between this force and the Newtonian attraction. Perſuaded that nature is ſimple and uniform, they concluded that the property of mutually uniting muſt depend on that of attraction, which all bodies are known to poſſeſs. They have formed a compariſon between the ſmall bodies which are acted on by the affinities, and the large maſſes that compoſe the univerſe; and have conſidered the approach of the former to each other to combine, as a conſequence of their mutual gravitation. It is by adopting and modifying this opinion, that certain writers have concluded that the force of affinity follows the ratio of the weight, and that the heavieſt body poſſeſſes the power of combination in the ſtrongeſt degree. This hypotheſis ſometimes agrees with facts,* as may be obſerved with regard to many acids, eſpecially in their action on metallic ſubſtances. Laſtly, ſome chemiſts have been ſo firmly perſuaded, that there is the moſt perfect relation between attraction and chemical affinity, that they have imagined it poſſible to meaſure and compute its force from the adheſion that takes place between bodies. M. de Morveau, whoſe opinion is of ſuch authority as to lead that of other philoſophers, has made ſome experiments with a view to prove this aſſertion. Theſe experiments conſiſted in applying to the ſurface of mercury, metallic plates of equal diameter, ſuſpended from the arm of a balance, whoſe other extremity carried a diſh as uſual. In this laſt he placed weights, till their force became equal to the ſeparation of the metallic plate from the ſurface of the mercury; and he found by comparative trials with different metals, that their adherence to the mercury was various, and agreed ſufficiently near with their affinities with that fluid. That is to ſay, he found that gold adhered the ſtrongeſt of all to the mercury, while cobalt, which is ſcarcely capable of uniting with it, was raiſed very eaſily from its ſurface, with which it has little or no adheſion. We muſt here take the liberty of obſerving, that experiments of this nature are ſubject to error, becauſe the lower ſurface of the metal muſt combine with the mercury; and the portion of amalgam formed in theſe circumſtances being naturally more conſiderable where the metal unites the moſt readily with the mercury, will then add moſt to the weight, and conſequently require the greateſt force to lift it up from the ſurface of the mercury. This objection ſeems to be ſufficiently forcible to deſerve the attention of the celebrated author of theſe experiments.

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* This hypotheſis cannot be brought to the teſt of experiment, and muſt therefore reſt, like many others, intirely on its analogy with the phenomena that ſuggeſted it. The force of affinity may depend on, or be proportional to, the ſpecific gravity of the particles; but that ſpecific gravity has no ſort of relation to, and conſequently is not deducible from, the ſpecific gravity of the aggregate. To mention one, among innumerable inſtances in proof of this aſſertion; it is found that fixed air compoſes more than one third of the weight of calcareous ſpar, whoſe denſity is nearly three times that of water; but when diſengaged, occupies many hundred times the former ſpace. Can the ſpecific gravity of its particles be inferred from either ſtate? Certainly not. T.

It is evident, from what has been here related concerning the opinions of philoſophers, that the cauſe of the attraction of affinity is very far from being known; and that if it be the ſame with the attraction of gravitation, the difference of the laws which it follows, compared with thoſe of gravity, ſhew that it is peculiarly modified. This truth may be eaſily aſcertained, by comparing the knowledge we poſſeſs concerning the attraction admitted by Newton, with that which we begin to have concerning chemical affinities. In reality, the former does not ſenſibly ſhew itſelf, but between large maſſes, and is in the direct ratio of the quantities of matter; whereas the latter is not obſerved, but between very minute bodies, and is abſolutely inſenſible when the bulks are conſiderable. The former exerts its power at immenſe diſtances; but the latter does not exiſt but between bodies in contact, or nearly ſo. We have already exhibited a part of the compariſon, in examining the laws of the chemical force we are inquiring into; and we believe after all theſe reflections, that the difference between theſe two natural phenomena is ſufficiently marked to render it incumbent on philoſophers to make a diſtinction between them.

If we might preſume to give our ſentiments on this ſubject, we think that it is as impracticable in the preſent ſtate of our knowledge to diſcover the cauſe of the chemical affinity, as it has hitherto been to aſſign that of gravity, magnetiſm, &c.; and that the ſciences will be much more promoted by examining, without intermiſſion, the appearances that preſent themſelves, and by multiplying the laws, if poſſible, than by indulging in ſpeculations, which are always uncertain, and too frequently founded in error.

CHAP. IV.

Concerning the Principles of Bodies.

PHiloſophers in every age have admitted, that all the variety of natural bodies are formed of primary ſubſtances, more ſimple than themſelves, which they have diſtinguiſhed by the name of principles. Chemiſts, who have the ſtrongeſt conviction of this leading truth from their analyſes, have formed ideas, ſufficiently preciſe, of the nature and difference of theſe principles; and have even admitted of ſeveral kinds or claſſes. It muſt, however, be remarked, that they uſe the word principle in a different ſenſe from that adopted by the ancient philoſophers. For Ariſtotle and Plato did not regard any ſubſtances as principles, but ſuch as are too minute to be perceived by the ſenſes, and form, by their aſſemblage, bodies ſomewhat leſs ſimple, which are within the ſphere of perception, and were by them called elements; a name ſtill retained, and applied in the ſame ſenſe. Theſe are what other philoſophers have called atoms, or monades. But chemiſts, not chuſing to enter raſhly into ſpeculations of ſuch ſubtlety, apply the term principle in general to all bodies, whether ſimple, or more leſs compounded, which they obtain in their analyſes. Yet as principles, conſidered in this point of view, are very different from each other, they have divided them into proximate and remote principles. The firſt are ſuch as are ſeparated by a firſt analyſis, and may themſelves be compoſed of others; as for example, in decompoſing a vegetable ſubſtance, oils, mucilages, ſalts, and colouring matter, are ſeparated from each other, and are the proximate principles from which, by new operations, other principles may be had. Theſe other are the remote principles. Thus mucilage, which is a proximate principle of plants, affords by a new analyſis, acid, water, and earth, which are the remote principles of the plant. Other names have alſo been given to theſe two orders of principles, ſuch as principiated principles applied to thoſe before called proximate, and principiant principles to thoſe called remote. Theſe words imply, that the firſt are compoſed of other principles, and that the laſt are ſuch as ſerve to form or conſtitute others more compounded. Some chemiſts, for greater accuracy of diſtinction, admit ſeveral orders of principles. They call the moſt ſimple by the name of primitive, primary, or firſt principles. Principles compoſed of the moſt ſimple kind united are called ſecondary, or principles of the ſecond order. Principles of the third order are compoſed of this laſt, &c.

The number of elements has not been always the ſame among philoſophers. Some with Thales the Mileſian, who was placed in the rank of the ſeven ſages of Greece, on account of his uncommon acquiſitions in knowledge, and who, according to Cicero, was the firſt of the Grecians who applied himſelf to natural philoſophy, have regarded water as the principle of all things. According to Anaximenes, air occupies this firſt place, and he did not ſcruple to deify this element, on account of its great importance. Others beſtowed the chief dignity upon the earth; the leader of whom was Anaximander, the diſciple of

Thales, and maſter of Anaximenes. Every one found reaſons to ſupport his own opinion; but as the true method of conducting chemical and philoſophical inquiries was not then known, we can only eſteem theſe early notions as ſpeculations, void of all foundation. About three centuries after the time of theſe philoſophers, Empedocles, a phyſician of Agrigentum, thinking that the ſimplicity of the four ſubſtances contended for as the principle of all things to be equal, united their opinions, by admitting of four elements, fire, air, earth, and water. In the ſucceeding age, Ariſtotle and Zeno, adopted this opinion of Empedocles. When we reflect on the reaſons that may have engaged theſe philoſophers to regard fire, air, earth, and water, as elements, we are tempted to believe, that it was not ſo much in conſequence of the accurate knowledge they could have acquired concerning theſe bodies, as in conſideration of the magnitude or quality of them, and the conſtancy or invariability of their properties. Fire exiſts every where, and its effects are always the ſame. Our globe is ſurrounded by a maſs of air, whoſe eſſential properties do not ſeem ſubject to variation. Water is preſented to obſervation on the ſurface of the globe, in an immenſe maſs, that fills up or conceals its abyſſes or cavities. And laſtly, the globe itſelf, whoſe volume far exceeds that of all the creatures that inhabit it, ſeems to be formed of a ſolid matter, little ſubject to change, capable of fixing or ſerving as a baſe for the other elements. It appears, therefore, that it was from conſiderations, founded on the bulk and apparent immutability of theſe bodies, that the early ſages were induced to regard them as the materials uſed by nature in the formation of all other beings.

The peripatetic doctrine which prevailed in the ſchools, preſerved the Ariſtotelian diſtinction of elements, till the ſixteenth century. At that period, the ſect of chemiſts, which began to prevail againſt the others, admitted a new diviſion of primary ſubſtances. Paracelſus, who was more of the artiſt than of the philoſopher, drew immediate inferences from the reſults of his operations, and acknowledged five principles; ſpirit, or mercury; phlegm, or water; ſalt; ſulphur, or oil; and earth. By ſpirit, or mercury, he underſtood every volatile and odorous ſubſtance, though ſimplicity is far from being a conſtant attendant on theſe properties. Water, or phlegm, comprehended in his ſyſtem, all the aqueous and inſipid products, and is liable to the ſame objection with reſpect to its pretended ſimplicity. The word ſulphur, or oil, denoted all inflammable and liquid ſubſtances, and conſequently a great number of bodies more or leſs compounded, as the fat and eſſential oils, &c. By ſalt, he indicated every dry ſubſtance poſſeſſing taſte and ſolubility, qualities that belong to a great number of compounds. Laſtly, the word earth was applied in the doctrine of Paracelſus, to the dry, fixed, and inſipid reſidues of operations, all of which are now known to differ exceedingly from each other.

Beccher, a chemiſt, who has treated his ſubject in the moſt philoſophical manner, was aware of the objections that might be urged againſt the doctrine of Paracelſus, and from a conviction of its inſufficiency, he took another method of arriving at the elements of bodies. He firſt diſtinguiſhed two principles very different from each other, humidity and dryneſs, water and earth. He divided this laſt into three ſpecies; namely, the vitrifiable, inflammable, and mercurial. Vitrifiable earth, according to him, was that which alone poſſeſſed the greateſt immutability; but when mixed with ſome ſaline earth, was capable of forming the moſt perfect glaſs. He likewiſe attributed to it the property of rendering the combinations into which it entered ſolid, and little ſubject to change. The inflammable earth was known by the combuſtibility of the combinations it enters into. Beccher regarded it as the cauſe of ſmell, colour, and volatility. The mercurial earth he ſuppoſed to exiſt in mercury, arſenic, marine acid, &c. &c.; and its peculiar character was that of giving a very conſiderable volatility and ſpecific gravity to the compounds in which it exiſted. Stahl adopted, and commented on the doctrine of Beccher. He regarded the inflammable earth as fire fixed in bodies, and gave it the name of phlogiſton. He could not ſucceed in demonſtrating the exiſtence of mercurial earth, and there has nothing been done to this day, which at all eſtabliſhes it. Stahl paid the greateſt attention to combinations containing earth, water, and eſpecially phlogiſton; but he has ſaid nothing concerning air, which Hales, nearly at the ſame period, proved to be a principal agent in chemical phenomena.

From the time of Beccher and Stahl to the preſent, no change has been made by chemiſts in the doctrine of the elements laid down by the ancient philoſophers. Like Empedocles, they have acknowledged four elements, and have conſidered each in two different ſtates. 1. As free, or inſulated; in the large maſſes of air in the atmoſphere, fire taken in general, water, and the earth attended to at large. 2. Or as combined; in which kind of inquiry their buſineſs has been to obtain the component part by analyſis.

Such were nearly the opinions adopted reſpecting the principles of bodies, from the time of Beccher and Stahl, till the valuable

able diſcoveries of Prieſtly and Lavoiſier, on fixed air and combination, neceſſarily introduced new opinions. In fact, if immutability of properties, unity, and ſimplicity, be the true characters of elements; and if it be admitted that this ſimplicity no longer exiſts, when a body is found to be capable of decompoſition, it muſt be remarked: 1. That among the four elements there are at preſent two, namely, air and water, the principles of which, art has ſucceeded in decompoſing and ſeparating. 2. That the exiſtence of fire, in the ſenſe of the word, as uſed by philoſophers and chemiſts, taken to be a peculiar fluid always identical, is very far from being proved; and that many reaſons, and eſpecially the various modifications of fire, tend to weaken the probability of its being ſuch, as we ſhall ſhew in the following chapter. 3. That water itſelf, which ſeems to have the moſt ſtriking characters of ſimplicity and uniformity of ſtructure, has not reſiſted the late expedients uſed by chemiſts; and that M. Lavoiſier has ſucceeded in decompoſing it into ſeveral aeriform fluids; a decompoſition which had already been in ſome degree exhibited by the differences of appearance ſhewn by this pretended element in a variety of circumſtances. 4. That elementary earth is a creature of the imagination; ſince it can be ſhewn, that there are many earthy ſubſtances equally ſimple and incapable of decompoſition, as will be done in the concluding chapter of this firſt part.

From this general enumeration of facts hereafter to be more fully explained, it follows, that we are not acquainted with any ſimple or unchangeable ſubſtances; that the true principles or firſt elements of bodies elude our ſenſes and our inſtruments; that ſuch as are called elements are far from being ſimple, though they are ſo denominated on account of their influence in natural phenomena, and their exiſtence in a very great number of products. Theſe aſſertions agree with the opinions of ſome of the ancient philoſophers, who did not regard the elements as the moſt ſimple bodies, but ſuppoſed them to be formed of principles of a far greater degree of tenuity and unchangeableneſs.

Theſe notions concerning thoſe bodies, which have for ſo many ages enjoyed the title of elements, and to which we deny that prerogative, do not prevent us from conſidering fire, air, earth, and water, as the moſt ſimple, or rather the leaſt compounded of the ſubſtances we know. And as we meet with theſe bodies in the analyſis of every natural product, of which they conſtitute the ſecondary principle, it will not be improper to conſider them as elements under that point of view.

We will finiſh this detail by explaining a kind a kind of nomenclature adopted by certain methodical writers, in diſtinguiſhing bodies, according to the order of the principles that enter into their compoſition.

If two elements or principles are united or combined together, there reſults a body called a mixt. A number of mixts form a compound. Two compounds united form a ſurcompound. The combination of ſurcompounds produces a decompound, and theſe laſt, in like manner, generate ſurdecompounds. It is not eaſy to give examples of theſe different kinds of compoſition, as we can ſcarcely proceed ſo far as ſurcompounds. Theſe diſtinctions appear, therefore, to be ideal, and of no uſe. M. Macquer, to whom chemiſtry is indebted for much of its perſpicuity, propoſes to change this barbarous and inaccurate nomenclature, and inſtead of it to ſubſtitute the words compound of the firſt, ſecond, third, &c. order. Or we may adopt the ſame terms to diſtinguiſh chemical principles in the order of analyſis by which they are obtained, inſtead of the order of their compoſition.

CHAP. V.

Concerning Fire.

THOUGH we neither admit of the word element in the ſenſe uſually applied to it, nor entertain the opinion that the four bodies, ſo called, are the immediate principles of all others, or the moſt ſimple in nature; yet we think it neceſſary to attend to them in the firſt place, becauſe the hiſtory of their properties will be uſeful in the explanation of thoſe of the other bodies, of which we ſhall hereafter treat; and in the next, becauſe they cannot be ranged in any order relative to natural hiſtory, becauſe they are common to all the kingdoms of nature.

Among the four bodies called elements, no one appears to be more active, nor at the ſame time more ſimple, than fire. The moſt ancient philoſophers, and after them philoſophers in every age, have given this name to a ſubſtance which they ſuppoſed to be a fluid extremely moveable and penetrating, formed of particles continually agitated, by them regarded as the principle of fluidity and of motion. When we reflect on this ſubject, we ſhall find that theſe properties could only be attributed by conjecture to a body placed among the elements, ſince its exiſtence has never been demonſtrated; as that of the three other elementary ſubſtances has always been. It is, indeed, natural to think that this name, fire, has in all languages and times, been given to the impreſſion that heated bodies communicate, or make on the ſenſes: and which is ſynonymous to the term heat, as well as to the light that bodies emit when in combuſtion. The Chancellor Bacon is one of the firſt who doubted the exiſtence of fire as a peculiar fluid, and took notice that philoſophers in defining it, had always miſtaken a property for a ſeparate ſubſtance. Boerhaave, whoſe treatiſe on fire will always be regarded as a maſter-piece, was ſenſible of this difficulty, and in order to render the properties of this pretended element more evident, he examined its effects on bodies wherein it is thought to exiſt; ſo that he, like all the philoſophers who preceded him, has written a hiſtory of heated, luminous, rarified, burning bodies, rather than that of fire itſelf. This confuſion is likely to be always found in natural philoſophy; for the properties of fire are neceſſarily connected with thoſe of the bodies whereon it acts; ſo far from having it in our power to inſulate it, we cannot even form an idea of its ſeparate exiſtence: and notwithſtanding the advanced ſtate of chemiſtry,

miſtry, it has not been found poſſible to ſeize and confine this principle, which philoſophers ſeem agreed to call a fluid, and whoſe effects they explain with ſufficient facility, when, led by cuſtom, they regard its exiſtence as well eſtabliſhed. Theſe difficulties have cauſed ſeveral chemiſts, and in particular Macquer, to believe, that fire is nothing elſe but light, and that heat is a modification of bodies ariſing from the motion and colliſion of their particles. This opinion, however, is not generally received. To form an adequate notion of the different theories propoſed reſpecting fire, we muſt not confine our attention to general poſitions. The only method of attaining exactneſs, and to throw light on the immenſe number of facts that compoſe the ſcience of chemiſtry, is to divide the ſubject, and examine its parts ſeparately. We ſhall conſider, in ſucceſſion, as ſo many particular effects of fire, light, heat, rarefaction, phlogiſton, the changes produced in bodies by heat, and, laſtly, the advantages ariſing to chemiſtry from their changes.

§ 1. Concerning Light.

We cannot entertain the ſame doubt concerning the exiſtence of light, as of fire, becauſe its exiſtence and properties are at preſent well known and eſtabliſhed. This ſubſtance, emitted from the ſun and fixed ſtars, is the cauſe in moſt caſes of our perception of other bodies. This matter, reflected in right lines from the ſurface of bodies, is the cauſe of the ſenſation of ſight, by producing an image of external objects on the retina of the eye. By the aſſiſtance of a darkened chamber, means have been found to examine its peculiar properties ſeparate and diſtinct from thoſe of the bodies from which it is emitted.

The extreme velocity of light is ſuch, that it paſſes through the ſpace of 80,000 leagues * in a ſecond, according to the moſt eminent aſtronomers. Its motion is rectilinear, and of courſe divergent from the point which emits it, and the elaſticity of the rays, or the re-action of the power that reflects them is ſo perfect, that the angle of their reflection does not ſenſibly differ from that of their incidence, as is ſhewn by writers on catoptrics. When light paſſes near any ſubſtance whatever, it is more or leſs inflected, and this inflection, proving that it is ſubject to attraction, is an evidence of its exiſtence.

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* Of 25 to the degree, or 167,000 geographical miles. T.

Notwithſtanding the velocity of light, it is eaſily deflected out of its courſe, as well by the bodies it paſſes through, as by thoſe it paſſes near. When its courſe is oblique from a rare medium into a denſer, it is refracted, or ſuffers a change in its direction like other ſolid bodies; but Newton * diſcovered that its refrangibility is towards the perpendicular, inſtead of being towards the oppoſite part, as is the caſe with other bodies. For a more minute detail of the properties of light, reference muſt be made to books written expreſsly on the ſubject of optics.

When light arrives at the earth's ſurface, and preſents to our ſight the variety of bodies, which it would otherwiſe be impoſſible to diſcern, we find that the mode of action of thoſe bodies on light is ſuch as to diſtinguiſh them into tranſparent or opake, and coloured. Tranſparency is the property of admitting the rays of light to paſs eaſily through any ſubſtance, and doubtleſs ariſes from the form of the pores. † As this property is found in the heavieſt and

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* Newton did not diſcover this. Des Cartes firſt publiſhed the diſcovery of the conſtant ratio of the ſeries of incidence and refraction; though it was certainly known before to Willebrord Snellius, and Kepler was very near diſcovering it. T.

† The minuteneſs of the particles, and ſmallneſs of the pores. See Newton's Optics. T.

hardeſt bodies, it muſt follow as a conſequence that the tenuity of light is extreme. When thus tranſmitted, the refractions it undergoes are in proportion to the denſities, when the bodies are either ſtones, ſalts, or glaſſes, but is greater when the bodies are of the claſs of combuſtibles. Thus yellow amber has a greater refracting power, than a ſaline cryſtal of equal denſity.

It was by an examination of the refractions and reflections of light, that Newton ſucceeded in decompoſing, or rather diſſecting this body, and in proving that the different rays, which compoſe a beam of light, are each capable of exciting the idea of a different colour. Before his time, very little was known reſpecting the cauſe of colour. As each kind of ray is differently refrangible as well as reflexible, it is found that a beam of light received on a priſm of glaſs is ſeparated into its various component rays by refraction as it paſſes through, and being intercepted at ſome diſtance by a white plane, or body equally capable of reflecting all, they form a long ſpectrum, conſiſting of the colours in the following order, namely, red, orange, yellow, green, blue, indigo, and violet; the red being compoſed of ſuch rays that have been the leaſt refracted out of their courſe, and the others being more and more refrangible in their order.

The particles at the ſurfaces of opake bodies appear to produce an effect on light reſembling that of the priſm.* It is on this property of the particles, that all the variety of colours, which charm the ſight, depends. The fact is, that bodies are white, when they reflect or return back all the rays of light that fall on them; and, on the contrary, when all the rays are abſorbed, we perceive a defect of light, which we call black, and is in reality the abſence of all colour: and again, every beam of white light being compoſed of a ſeries of the ſeven primary colours, and of every poſſible intermediate tinge, all differing in reflexibility, each particular body will appear of the colour it is conſtructed to reflect, while it abſorbs the greater part of the rays of every other colour. Colour, therefore, depends on the nature of the ſurface of the bodies, as tranſparency does on their pores, and both depend on the habitudes of bodies with reſpect to light. Thus, for example, the colour called blue, or red, is produced in bodies by an abſorption of all the other rays, except the blue or red, which are reflected back.

Theſe are the chief properties of light conſidered as emitted from the ſun or the fixed ſtars. But ought we to confine our inquiries reſpecting this ſubſtance to its free and inſulated ſtate. Does it not, like every other body we are acquainted with, obey the laws of affinity in the ſame manner as it is found to be ſubject to attraction? This conjecture is rendered more probable, by the conſideration that the effects of light do not ſeem to be confined to its mere re-action on bodies that modify or alter its courſe. If it be true, that bodies expoſed to the contact or impulſe of light, experience an alteration or change of nature without any other evident cauſe, it muſt follow, that light itſelf is the agent, and produces its effects by a chemical force, or affinity. Though it has not yet been poſitively decided, whether their changes ariſe from the decompoſition of light itſelf, or of the bodies thus altered, or of both together, the facts are too numerous and too ſtriking to be overlooked. We ſhall content ourſelves with mentioning in this place only ſuch as are of the moſt conſequence, and the beſt eſtabliſhed; as it is our intention to treat the ſubject more fully in our hiſtory of each natural body in its order.

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* The ſeparation of light into coloured rays, in conſequence of its falling on tranſparent particles of definite magnitude, (and all minute bodies are tranſparent) has not yet been ſhewn to be of the ſame kind, or performed in the ſame manner, as the ſeparation effected by the priſm. T.

Natural philoſophers have long been aware of the influence of light on vegetation. It was firſt obſerved, that plants growing in the ſhade are pale, and without colour. Herbs that grow beneath ſtones are white, ſoft, aqueous, and of a mild or inſipid taſte; and gardeners avail themſelves of the knowledge of this fact to furniſh our tables with white and tender vegetables, by binding up and compreſſing their leaves together, ſo as to defend them from the contact of light. The more plants are expoſed to the ſolar rays, the more colour they acquire. Such, therefore, is the origin of thoſe colouring matters, of ſo much value for their livelineſs and body, which many of the eaſtern nations extract from woods, bark, and roots, and which the utmoſt induſtry of the Europeans has not ſucceeded in imitating.

Colour is not the only property that is obtained by vegetables from the contact of the rays of light. Taſte, odour, and combuſtibility, are likewiſe derived from the ſame ſource. Light contributes greatly to the maturity of fruits and ſeeds; and is the cauſe why, under the burning ſun of America, vegetables are in general more odoriferous, of a ſtronger taſte, and more abounding with reſin. From the ſame cauſe it happens, that hot climates ſeem to be the native country of perfumes, ſtrong ſmelling fruits, dying woods, and reſins of various kinds. Laſtly, the action of light is ſo powerful on the organiſm of vegetables, as to cauſe them to pour forth torrents of vital, or pure air, into the atmoſphere, while expoſed to the ſun-ſhine; whereas, on the contrary, when in the ſhade they exhale nothing but a noxious fluid, or true aerial acid, ſimilar to that obtained from chalk, and known by the name of fixed air, or acid of chalk. This important diſcovery due to Dr. Prieſtley, and more minutely inquired into by M. Ingen-houſze, ſhews in a ſtriking manner the influence of light on vegetation. The effects of light are equally ſeen in a great number of chemical operations. There is not a ſubſtance, which in well cloſed glaſs veſſels, and expoſed to the ſun's light, does not experience ſome alteration from this cauſe. Among theſe, the mineral acids, the metallic calces, vegetable powders, and volatile animal oils, are moſt ſingularly changed. Metallic calces, in general, eſpecially thoſe of mercury, become of a deeper colour, by expoſure to the ſun; as may be ſeen by obſerving painters colours preſerved in powder in the ſhops.* The mineral acids, by the ſame treament, become more volatile and fuming. Metallic ſalts grow black, and animal oils take an obſcure brown. All theſe changes deſerve the greateſt attention of chemiſts, though they have not hitherto been ſtrictly inquired into. Scheele is the only chemiſt who has deſcribed ſome of them; and we propoſe to return again to this ſubject in the following parts of our work.

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* It has been remarked, however, that the parts of a room painted with white lead and oil, which are defended from the light by furniture, or by keeping the windows cloſed, become of a darker colour than the reſt; and that the action of light permitted to fall on ſuch obſcure parts of the ſurface, in ſome meaſure reſtores the original colour or whiteneſs. T.

§ 2. Concerning heat.*

The difficulties that attend the inquiry concerning heat are much more numerous than

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* The importance of the theory of heat in chemical inquiries has induced the tranſlator to give a more ſtrict and leſs diſcurſive view of the ſubject than is exhibited in the text.

1. Temperature is the ſtate by which a body poſſeſſes the power of exciting the undefinable ſenſations of heat or coldneſs.

2. The word heat is uſed as a term to denote the cauſe of that ſtate.

It is to be obſerved, that the words temperature and heat are here taken in the moſt extended ſenſe. The organs of the human frame are not only imperfect when applied to meaſure the temperatures of bodies, but likewiſe exceedingly limited in this as well as in every other caſe. Temperature is therefore uſed to denote every degree of heat or coldneſs, whether within the limits of perception or not, and is appreciated by the obſervation of its effects on bodies.

Heat, conſidered as the cauſe of temperature and of other effects, is ſubject to variation. It is therefore an object of mathematical inquiry, as poſſeſſing quantity, either abſolutely, or in the ſame ſenſe as various attributes, ſuch as ratios or motion, are ſaid to poſſeſs it. But it is no part of this inquiry, whether heat be motion or matter. Perſpicuity requires that theſe objects ſhould be ſeparately attended to.

3. Bodies

than thoſe relating to light. It has not yet been proved by any phenomenon, that heat is a ſelf-

3. Bodies in contact, or communicating with each other, do, after a length of time, aſſume or acquire one common temperature.

4. The time of acquiring the common temperature is different in different bodies. A body, which quickly alters its temperature by communication, is ſaid to be a better conductor of heat than ſuch as alter more ſlowly.

5. When the temperature of a given ſolid is increaſed, there is a certain period at which it becomes fluid, and as the temperature is increaſed beyond this laſt point, the fluid takes a rare and elaſtic form with more or leſs rapidity, forming vapour. Whether an increaſe of temperature would convert vapour into a fourth ſtate, namely, that of a permanently elaſtic fluid, or air, has not been decided; but it is probable.

The temperatures at which different bodies aſſume the fluid or vaporous ſtates are exceedingly various. Some bodies, as for example, mercury, are not frozen but by extreme cold: others, as rock cryſtal, cannot be melted, but by the moſt vehement heat modern chemiſtry can excite: others again cannot be brought into ſome of the ſtates; and of theſe the rule is inferred from analogy, till future experiments may tend to clear up the matter

6. Univerſally the effects of an increaſed temperature are either (1) converſion of the whole body into fluid or vapour; or (2) decompoſition, by one or more of the chemical principles of the body being melted or volatilized; or (3) without change of ſtate or compoſition, an increaſe of the dimenſions, which laſts no longer than while the increaſed temperature remains.

7. Axiom 1. The quantities of heat in two equal bodies of the ſame kind and temperature are equal.

8. Theorem 1. The quantities of heat in bodies of the ſame kind and temperature are as their maſſes.

9. Theorem 2. Two equal bodies of the ſame kind, but different temperatures, being brought into contact; the hotter will impart half its ſurplus of heat to the other. For

a ſelf-exiſtent, a ſeparate ſubſtance; and many eminent philoſophers have embraced the opinion

For (by 3) they will acquire a common temperature by contact, and by that means (7), the quantities of heat will be made equal. This can only be effected by the hotter body imparting half its ſurplus.

10. Theorem 3. Two bodies of the ſame kind, but different temperatures, being brought into contact; the ſurplus of heat, by means of which the one exceeded the other in temperature, will be divided between the two bodies in proportion to their maſſes.

For (3) they will acquire a common temperature, and the whole quantity of heat in each will then (8) be in proportion to its maſs. This can only be effected by dividing the ſurplus in the ſame proportion.

11. Corollary 1. The quantities of heat required to be added to or taken from bodies of the ſame kind to bring their temperature to a given ſtandard will be as their maſſes.

12. Corollary 2. Hence a thermometer, with a very ſmall bulb, may be conſidered as poſſeſſing the temperature of the body it is in contact with, becauſe the common temperature will not ſenſibly differ therefrom when the body is of conſiderable magnitude.

13. The mercurial thermometer nearly meaſures the true increments of temperature.

This is determined by experiment (by De Luc). Let a thermometer be graduated ſo as to ſhew the equal increments (6) of the expanſion of the mercury; and the common temperature of two equal bodies of the ſame kind in contact (as for example, meaſures of water) will be nearly the arithmetic mean between the two original temperatures, as ſhewn by ſuch an inſtrument. The inſtrument therefore gives reſults nearly agreeing with deductions (9) made from the general phenomena of heat, or it nearly meaſures the true increments of temperature.

14. Axiom 2. If two equal maſſes at different temperatures be brought into contact, and the common temperature be either higher or lower than the arithmetical mean (9), the

opinion of Bacon, that it is nothing more than a modification, of which bodies are ſuſceptible.

(9), the ſurplus of heat, by means whereof the one exceeded the other in temperature will be unequally divided; and the diſpoſition to be heated, or the capacity or affinity for heat, is greater in one body than in the other.

15. Theorem 4. The capacity of equal maſſes for heat are inverſely, as the changes of temperature they undergo, when differently heated and brought into contact. And the contrary.

For the ſurplus of heat is divided into equal parts by the thermometer: of theſe parts, the hotter body loſes a certain number by communication to the colder, and retains the remainder. The number of degrees loſt conſtitutes the change of temperature in the hotter, and the remainder is the change in the colder. But cauſes are ever proportional to their effects: therefore the capacities are as the proportions of heat retained by each; that is, inverſely as the changes of temperature.

16. Corollary 1. Hence if any given body, as for example, fluid water, be aſſumed as a ſtandard, the capacities of other bodies being experimentally found, may be ranged numerically, ſo as to form an uſeful table.

17. Corollary 2. The quantities of heat required to be added to or taken from bodies of equal maſs, to bring their temperature to a given ſtandard, will be as their capacities.

18. Corollary 3. The quantities of heat required to be added to or taken from bodies in general, to bring their temperature to a given ſtandard, will be as their maſſes (11), and their capacities jointly.

19. Corollary 4. The capacities, in general, will be directly as the quantities of heat ſo taken, and inverſely as the maſſes; or they will be in the inverſe ratio of the changes of temperature, and the maſſes of two bodies placed in contact. This, in the form of a practical rule, is, multiply the weight of each body by the number of degrees between its original and the common temperature, and the capacities of the bodies for heat will be inverſely as the products.

20. Theo-

ceptible. It is certain that philoſophers, as well as the common rank of men, have always

20. Theorem 5. The whole quantities of heat contained in bodies of equal maſs and temperature are as their capacities.

For if the temperatures of various bodies be ſuppoſed gradually and equally to diminiſh till the abſolute privation of heat be obtained, the quantity of heat given out in any portion of the time (17) will be proportional in each body to its capacity. And the whole time being made up of ſuch portions, the reſpective ſums of the quantities of heat given out by each body will be in the ſame ratio.

It is the buſineſs of experiment to determine whether the ratios of the capacities be the ſame in all temperatures, cæteris manentibus.

21. Scholium. From the foregoing theorem, many writers have called a table of capacities by the name of a table of ſpecific heats. Theſe terms, which ſeem improper, or at leaſt unhappy, becauſe applied to quantities that continually fluctuate, have certainly rendered the theory of heat leſs eaſy to beginners.

22. As far as experiments have hitherto been made, it is found that the capacity of a given body for heat is leaſt when ſolid, greater in the fluid ſtate, and greateſt in the vaporous ſtate.

Thus for example, ice and water being expoſed in equal quantities to ſimilar heating matters, as before a fire, the ice will be melted without increaſe of temperature, while the water acquires 162 degrees of Fahrenheit's thermometer. Or equal parts of water at 162, and ice at 32° being mixed, the ice will melt, and the whole, inſtead of the mean temperature, will remain at 32°. In either caſe the ice requires 130° of heat, which produces no other effect than rendering it fluid, and is not ſhewn by the thermometer. So likewiſe the condenſation of ſteam, though little if at all hotter than boiling water, communicates much more heat to a refrigeratory than the ſame quantity of water equally hot, and therefore it contained more heat. The quantity of heat which conſtitutes the difference between the always ſuppoſed heat to indicate the preſence of fire, and have ſometimes taken it for the element

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the ſeveral ſtates of the body, has been improperly called latent heat.

23. Problem. The ratio of the capacities of the ſame body in the ſolid, and the fluid ſtates, and alſo the number of degrees the fluid would increaſe in temperature by the heat which would ſimply melt the ſolid, being given; it is required to determine the number of degrees of the ſame thermometer between the natural zero, or abſolute privation of heat, and the temperature of the ſolid juſt melting.

The whole quantity of heat in the ſolid when juſt melting, will be denoted by the number of degrees of its temperature from the natural zero: and the whole quantity of heat in the fluid will be denoted by the ſame number added to the number of degrees the temperature of the ſolid would have been raiſed by the heat applied to melt it, if its capacity had not been changed by melting. This laſt number conſiſts of the obſerved increaſe of temperature in the fluid augmented in the inverſe ratio of the capacities (15). Now the capacities of the ſolid and fluid being as their whole quantities of heat (20), it will follow that

The difference between the numbers expreſſing the capacities,
Is to the number expreſſing the capacity of the ſolid;
As the difference between their reſpective quantities of heat, in thermometrical degrees of the ſolid,
Is to the number of degrees expreſſing its whole quantity of heat, or its temperature from the natural zero.

This, in the form of a practical rule, is, multiply the number expreſſing the capacity of the fluid into the number of degrees the fluid would have increaſed in temperature by heat, ſufficient to melt the ſolid; divide this product by the difference between the numbers expreſſing the capacities, the quotient will be the number of degrees of temperature from the natural zero.

This problem is Dr. Irwine's, of Glaſgow.

element itſelf, and on other occaſions for one of its characters.

Its

From experiment, it appears, that the natural Zero is 1268 degrees of Fahrenheit's ſcale below 0 or 1300 degrees below the freezing point of water.

24. Corollary. The difference between the zero of any ſcale, and the natural zero, being once determined from experiment, it will be eaſy in all caſes, where any two of the three quantities, the capacity of the fluid, the capacity of the ſolid, and the number of degrees the fluid would be raiſed by heat ſufficient to melt the ſolid, are given to find the third.

25. The foregoing theory of heat may be applied to explain all the changes of temperature in bodies from the utmoſt violence of ignition to the moſt intenſe cold. For whenever by condenſation or freezing, or by a change in the chemical combinations of bodies the capacities are diminiſhed, a part of the heat contained will (15) be applied in raiſing the temperature. And on the contrary, cold will be produced whenever bodies are melted, or evaporated, or any chemical proceſs goes forward, by which the capacities are increaſed.

26. The grand queſtion, whether heat be merely a vibration of the parts of bodies, or a peculiar fluid is not decided. If heat be merely vibration, it will be ſcarcely poſſible to account for its not being univerſally communicated to bodies according to their maſſes, as the eſtabliſhed laws of motion require; but if heat be a peculiar fluid, the notion of a greater or leſs capacity for that fluid, whoſe variations of denſity will be the cauſe of change of temperature, will very naturally account for the different quantities required to be imbibed or given out by bodies of equal weight, before a like denſity or temperature can be produced in all. Neither will it be at all difficult, according to this hypotheſis, to give very probable accounts of what happens when bodies change their ſtates of ſolidity, fluidity, or vapour.

27. The various theories reſpecting heat, conſidered as matter, and a component part of bodies, are not ſufficiently

grounded

Its leading properties are to penetrate all bodies, to diffuſe itſelf uniformly, ſo as to tend to an equilibrium, to dilate the ſeveral ſubſtances it penetrates, and, laſtly, to cauſe them to aſſume the ſtate of fluidity, and afterwards that of vapour.

Bodies become heated in general in three manners, either by the contact of another heated ſubſtance, or by motion, or by the act of combination. Every one muſt have obſerved, that in mixing two ſimilar fluids, the one ſenſibly hot, and the other cold, the former loſes part of its heat by communication to the ſecond, and the temperature becomes equal in each; and the ſame is true of ſolid bodies that have remained a ſufficient time in contact. The developement of heat by means of motion is equally well known. Two hard ſtones, or pieces of wood, or ivory, or metallic matters ſtrongly rubbed or ſtruck together, produce a degree of heat, that in many caſes proceeds even to ignition.

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grounded on deciſive facts to admit of a curſory diſcuſſion in this place, or indeed to be ranked with the eſtabliſhed doctrines collected and arranged in this preſent note, though it muſt be allowed that ſeveral of them do honour to the genius and abilities of their inventors. Dr. Black of Edinburgh, Profeſſor Wilcke of Stockholm, Dr. Irwine of Glaſgow, Dr. Crawford of London, are among the leading names of philoſophers who invented and illuſtrated this excellent theory here explained; and it is ſincerely to be wiſhed, that ſome cotemporary writer would ſettle their reſpective claims before the lapſe of time ſhall have rendered it difficult. T.

And the production of heat by the act of combination is evidently ſeen in the union of concentrated acids with water, quick-lime, pure alkalis, metals: and inflammation follows on the mixture of certain fluids, as the nitrous acid and oils.

The laws of the communication of heat between bodies were thought to be analogous to thoſe of motion, till the labours of Meſſrs. * Wilcke of Stockholm, Irwine of Glaſgow, Crawford and Kirwan of London, Lavo ſier and De la Place of Paris, ſhewed that nothing is leſs known or more difficult to be known than the progreſſion and communication of heat in the ſyſtems of bodies of unequal temperature. The very ingenious experiments of theſe philoſophers are not yet ſufficiently numerous, and they themſelves depend too little on their general reſults to admit of their being regarded as part of the elements of chemical ſcience. It is, however, very probable that they will lead the way to the eſtabliſhment of a general theory of heat, applicable to all the phenomena of chemiſtry, in every one of which it is concerned, either as being abſorbed or diſengaged.

The moſt accurate experiments have not yet produced any deciſive principles reſpecting the nature of heat, and chemiſts, as well as the philoſophers in other branches of natural

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* Dr. Black of Edinburgh is indubitably the father of the modern doctrine of heat. T.

tural ſcience are divided in their opinions concerning it. Some with Lord Chancellor Bacon, think that heat is nothing elſe but a modification of which all bodies are ſuſceptible, not exiſting independent of bodies, but conſiſting merely in the oſcillation of their particles. Such was the opinion of the late Mr. Macquer. This ſet of philoſophers ground their opinion on the following facts: Heat follows motion in all its phenomena, and appears to obey the ſame laws; it conſtantly accompanies motion increaſing and diminiſhing in the ſame proportion. If we except the differences it preſents in its communication or paſſage from one body to another, which do not appear reconcileable with that of motion, the analogy between both is ſtriking in all its other properties. That this hypotheſis may be the more readily admitted, it is obſerved, that bodies even of the greateſt denſity have a great number of cavities or pores, whoſe dimenſions may exceed that of the real matter of which the body in queſtion is compoſed. Theſe void ſpaces permit the particles to move with reſpect to each other, and to oſcillate in every direction. Theſe oſcillations eſcape our ſenſes, for the ſame reaſon as the parts and powers themſelves do, namely, their minuteneſs. And, laſtly, theſe philoſophers take notice that the contrary opinion of heat, being matter, has never been proved either from its being ſhewn to have gravity, or from the other properties aſcribed to it.

Many other philoſophers, and ſome chemiſts, on the contrary, believe that heat is a peculiar fluid, exiſting in bodies, all which it penetrates with greater or leſs facility. They diſtinguiſh this fluid in two ſtates, in combination or at liberty: the former is not ſenſible to our organs, nor indicated by the thermometer. It is in a ſtate of repoſe in bodies, conſtituting one of their principles. It is often diſengaged in decompoſitions, and then paſſes to the ſtate of heat at liberty, becoming ſenſible by its action on the thermometer, and on other bodies.* They are of opinion, that there is always a certain quantity of heat at liberty in the atmoſphere, and that it is this laſt, which, being abſorbed in many chemical operations, produces the increaſe of temperature we obſerve on ſuch occaſions. As all bodies that paſs from the ſolid to the fluid ſtate, and from this laſt into the ſtate of vapour, produce cold in the ſurrounding bodies, they ſuſpect that there is a great quantity of the matter of heat abſorbed by theſe bodies; and that when, on the contrary, fluid ſubſtances become concrete, and produce heat, this laſt is diſengaged from the ſubſtance that contained it, and has paſſed from a ſtate of combination to a ſtate of liberty.

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* There are two opinions concerning the change which temperature bodies undergo when they change their ſtate or their mode of combination: by ſuch changes it is found that heat is either abſorbed or given out; or to ſpeak more unexceptionably, the alterations of temperature are either leſs or greater than would have been inferred from general reaſoning. Some philoſophers ſay, that the capacities of the bodies are changed, and therefore require more or leſs heat to occaſion ſimilar mutations of temperature than they did before (ſee our note on p. 112); others affirm, that the heat which diſappears or appears has no relation to the capacity, but is either received in combination, as a principle of bodies, or given out as ſuch. Theſe poſitions are not matter of opinion, but relate to facts, about which philoſophers will acquire more knowledge by experiment than by reaſoning. If the natural zero be determined truly by Dr. Irwine's theorem, (note on p. 113) and the capacities of various bodies in their ſtates of ſolidity and fluidity, be found from direct experiment, the corollary to that

Mr. Scheele, who, as well as Mr. Bergman, is perſuaded that heat is a ſelf-exiſtent body, has, with great care, examined the phenomena it preſents as a chemical agent, capable of entering into combinations. He has even thought himſelf juſtifiable in concluding, from his experiments, that it is compoſed of pure air, which he calls empyreal air, and phlogiſton; and that it differs from

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that theorem will give the number of degrees the fluid would be raiſed by heat that would ſimply melt the ſolid. If this deduction ſhould be found in all caſes to agree with the facts, the former opinion is true; but if not, there is a portion of heat not accounted for, which, if heat be matter, may probably be a principle of bodies. Fiant experimenta. T.

light only in the relative quantity of this latter principle. But, however ingenious and true the reſults of the experimental inquiry he has entered into may be, his inductions concerning the nature and principles of heat, do not ſeem, in our opinion, to follow naturally, nor prevent our continuing to think that the analyſis of heat is not yet accompliſhed.*

Laſtly, Meſſrs. Lavoiſier and De la Place ſeem to ſuſpect that both hypotheſes are true, and take place at the ſame time, that is to ſay, that heat conſiſts in the exiſtence of a peculiar fluid, and in the inteſtine oſcillations of the parts of bodies excited by its preſence.

Whatever may be the nature of heat, the phenomena it preſents in chemical combinations and decompoſitions, are not the leſs certain, nor the leſs deſerving our moſt careful attention. A great number of facts have eſtabliſhed it as a certainty, that this body or modification is unalterable in itſelf, and is not deſtroyed or loſt. And theſe have induced Meſſrs. Lavoiſier and De la Place to give the following important principle as an axiom reſpecting the appearance or diſappearance of heat.

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* Our remarks on the labours of Mr. Scheele, are not in conſequence of any want of eſteem and reſpect for this learned chemiſt, who ſtands in the firſt rank among the improvers of the ſcience. After having reflected and conſidered, with great attention, his treatiſe on air and fire, tranſlated by the learned M. de Dieterich, Paris, 1781, we think that the new conſequences he has drawn are not warranted by the facts, becauſe he does not ſeem to have paid attention to the dephlogiſticated air, ſhewn to exiſt in acids and metallic calces, the preſence of which is ſufficient to explain all the phenomena which he attributes to the paſſage of heat, through the veſſels, and the decompoſition that takes place during this filtration. To underſtand theſe phenomena, our chapters on air, combuſtion, acids, metallic ſubſtances, &c. muſt be read. Note of the author.

" If in any combination or change of
" ſtate whatſoever, there be a diminution
" of free heat, this heat will appear again
" undiminiſhed when the ſubſtances return
" to their firſt ſtate; and reciprocally, if in
" any combination or change of ſtate there
" be an augmentation of free heat, this
" new heat will diſappear during the return
" of the ſubſtances to their original ſtate."

In rendering this principle more general, and extending it to all the phenomena of heat, they have uſed the following mode of expreſſion: " All variations of heat, whether
" real or apparent, which are experienced
" by a ſyſtem of bodies, in changing their
" ſtate, will be re-produced in an inverſe
" order, when the ſyſtem paſſes again to its
" firſt ſtate."

To meaſure the quantity of heat abſorbed or diſengaged in the different chemical phenomena, being an operation which, after what has been ſaid, muſt evidently appear to be of the higheſt importance; philoſophers have endeavoured to avail themſelves of means, by which the defects of thermometers might be ſupplied. Mr. Wilcke propoſed to eſtimate the quantity of heat from the quantity of ſnow to be melted by the bodies under examination; and Meſſrs. Lavoiſier and De la Place have contrived a certain and eaſy method of carrying this propoſal into practice. It conſiſts of a veſſel ſurrounded with ice, whoſe interior part can only be melted by the heat communicated or extricated from the ſubſtances incloſed therein; and this heat being determined by the quantity of water * carefully collected, will ſerve, according to circumſtances, to ſhew either the ſpecific heats of bodies, or the quantity of heat diſengaged or even abſorbed. The inventors have gone ſo far as to apply it, with ſucceſs, in the determination of the heat diſengaged in combuſtion or reſpiration. The brevity we propoſe to adhere to in this work, and the long detail it would require to give a proper account of the ingenious inſtrument contrived by theſe learned academicians, and the methods of uſing it, oblige us to refer the reader to their own work. †

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* From ſome attempts made by the ingenious Mr. Wedgwood to avail himſelf of this inſtrument, it ſeems that the capillary attraction of the pounded ice, retaining a portion of the water that ſhould flow out, and ſome unexplained circumſtances, where the vapour raiſed by bodies, at very high temperatures was found to freeze again, inſtead of paſſing out in the form of water, are impediments to its uſe. See the Philoſ. Tranſactions. T.

† See the Memoirs of the Royal Academy of Sciences for their Memoir, read June 28, 1783.

We ſhall conclude this ſection, by conſidering in what caſes heat and light reſemble each other, and the chief differences that appear to ſubſiſt between them. It is not to be concluded, that heat and light are the ſame thing, becauſe the rays of the ſun heat ſuch bodies as they fall on; for there are many caſes on the contrary, wherein there is much light without heat, as well as others where the heat is conſiderable, though no light appears. In fact, the phoſphorus, diamond, rotten wood, animal matters in putrefaction, ſhining inſects and worms, the rays of the moon reflected and concentrated by metallic mirrors, or by lenſes, preſent a ſtrong * light without ſenſible heat, and all natural bodies may be ſtrongly heated without becoming luminous.

The ſolar rays ſeem to produce heat merely by their impulſe on bodies, and the friction they ſuffer from ſuch as interrupt their paſſage. Opake bodies, of a red colour, and particularly when of a black colour, are found to be more quickly and ſtrongly heated than white and poliſhed bodies; an effect doubtleſs ariſing from the more numerous de-

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* All theſe and other lights that do not produce heat, are prodigiouſly weak, when compared with the direct light of the ſun. The moſt concentrated moon-light, in the focus of a mirror, is not more than the 300th part of the intenſity of common ſun-ſhine. Heat cannot therefore be expected. See Traite d'Optique par Bouguer, quoted by Prieſtley, in his Optics, p. 546. T.

flections the abſorbed ray ſuffers before its motion is deſtroyed, and perhaps from its combining with ſuch bodies, while white bodies reflect it almoſt totally.

As to the production of light by a ſtrong and continued heat, as is obſerved in the combuſtion of oils, fats, wood, the ignition of metals and ſtones, it depends on cauſes that by no means imply an identity between light and heat. When combuſtible bodies are ſtrongly heated, they produce that flame which ſupplies the abſence of the ſun, and produces ſimilar effects. But this light, the product of inflammation, may be contained either in the air, whoſe preſence is neceſſary for combuſtion, or in the combuſtible body, and no fact aſcertains that it is heat which is changed into light. The incaleſcence of incombuſtible bodies, in which we cannot admit the preſence of combined light, at leaſt not in the ſame ſtate as in combuſtible bodies, has been explained in a very ingenious manner by Macquer, in the article Fire, in his valuable dictionary. It ariſes from the ſtrong vibrations excited in the particles of theſe bodies by heat. Theſe vibrations diſpoſe the particles in ſuch a manner that their facets being continually agitated have the effect of a number of ſmall mirrors, which reflect, and throw directly to our eyes the light which exiſts in the air * in the night as well as in the day, and do not produce darkneſs, but when their directions are not towards the organs of ſight.

This compariſon of the effects of light and heat, leaves us therefore in the ſame uncertainty concerning the exiſtence of the latter, and even gives additional force to the hypotheſis of Bacon.

We have no certainty reſpecting heat, but the bare facts. The impreſſions of pleaſure or pain produced on animals, the dilation of all bodies, and the conſequent diminution of ſpecific gravity, its conſtant production by friction and colliſion, its reſemblance to motion, its tendency to equilibrium, its production and diſappearance in analyſes and combinations; and, laſtly, its more or leſs rapid paſſage or tranſition from one body to another; theſe are the principal phenomena with which it is neceſſary to be well acquainted, in order to apply heat to the beſt advantage in chemical operations.

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* The author has given Macquer's opinion, with fidelity and conciſeneſs; but the value of that opinion will be found to be very ſmall, when it is conſidered that it is a neceſſary condition that his ſyſtem of little mirrors muſt be placed without the boundary of the earth's ſhadow before they can receive or reflect the light which exiſts in the air, &c. T.

§ III. Concerning Rarefaction.

The moſt remarkable effect attributed to fire by philoſophers, and which is certainly produced by heat, is rarefaction. We have already remarked, that the principal effect of heat is to augment the volume of all bodies, without adding to their weight. This rarefaction ſeems, at firſt conſideration, to imply the intromiſſion of ſome ſubſtance into the pores of the rarefied body, producing the effect of a wedge, by ſeparating them. But when we reflect, that a body rarefied by heat, has acquired no weight, and that its ſpecific gravity is leſs than in its ordinary temperature, we become convinced that the pores are ſimply enlarged, and nothing more.

From the phenomena of the relative motion, by which the parts of bodies are removed from each other by heat, it is clear that this power acts in oppoſition to that attraction by which they adhere together. We may obſerve the attraction between bodies in three * different ſtates, perhaps not ſufficiently diſtinguiſhed from each other by philoſophers. The firſt combined with an original impulſe retains the planets in their orbits, and may be called planetary attraction. The ſecond, or terreſtrial attraction, is the cauſe of the property we call weight.

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* See note on p. 43.

And the third is that by which the parts of bodies adhere together, and have various ſpecific gravities, according to its intenſity. It is the attraction which produces aggregation, and which heat tends to deſtroy; and by diminiſhing this, it produces a great number of effects, combinations, decompoſitions, vegetation, animalization, &c.

Boerhaave, who has conſidered the effects of fire rather as a philoſopher than as a chemiſt, has laid down three rules, or laws, concerning rarefaction conſidered in general, which we will now proceed to examine.

LAW I.

All Bodies are dilated by Heat. ||

Though it be true in general, that almoſt every body in nature is dilated and rarefied by heat, it is neceſſary to make ſome remarks on this phenomenon. In the firſt place, all mineral ſubſtances without exception, experience a dilatation, which is greater the more intenſe the heat. This rarefaction is ſuch as to deſtroy the aggregation of a great number of them. But if this

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|| This law is univerſal in bodies ſo long as they retain the ſtate of ſolidity, fluidity, or vapour they happen to poſſeſs; and have ſuffered no change either in the combination or quantity of their chemical principles. If the rule be taken in this ſenſe, the exceptions of our author will not ſtand. T.

this law be applied to animal and vegetable matter, it is ſubject to ſome exceptions. It is true, that a certain degree of heat dilates their fibres, ſeparating them, and diminiſhing the denſity of their ſtructure; but a ſtronger heat ſuddenly applied, produces an oppoſite effect. Every one knows that parchment, vegetable and animal fibres, and wood itſelf, ſhrink and contract when quickly heated. We find even in ſome mineral ſubſtances a property contrary to this law. Soft and ductile clays are condenſed and hardened by fire, ſo as to loſe much of their dimenſions, and at the ſame time are ſo hardened, as to ſtrike fire with the ſteel.

LAW II.

Bodies rarefied by Heat, have all their Dimenſions enlarged.

A bar of iron increaſes both in length and thickneſs when heated. Philoſophers have contrived many inſtruments to exhibit and meaſure this effect of rarefaction. The pyrometer invented by Muſchenbrock, ſhews the dilatation of heated metallic bars to the 12,500 of an inch. This ſenſibility is obtained by the motion of expanſion being communicated through ſeveral levers, whoſe arms are of unequal length; ſo that the extremity of the laſt is moved through a ſpace ſufficiently large to give motion to a wheel, which carries an index or hand round a graduated circular plate, and ſhews the minuteſt changes of length in the bar under examination. But as this inſtrument is uſed only to ſhew the expanſion of metallic bars lengthwiſe, philoſophers have made an experiment with a cylinder of metal fitted to an orifice in a metallic plate, ſo as juſt to paſs through it when cold, and they find that the ſame cylinder, when heated, could not paſs. It is, therefore, eſtabliſhed, that bodies expand by heat in diameter as well as in length.

This phenomenon is well known to chemiſts, who find it neceſſary to leave ſufficient room in the iron grates they place in their furnace, which, without that precaution, are found to do injury by their expanſion.

LAW III.

The Dilation by Heat is directly as the Rarity, or inverſely as the Denſity of Bodies.

Boerhaave, in the eſtabliſhment of this law, compared the effect of heat on no more than three ſolid bodies, and theſe very different from each other, namely, wood, ſtone, and metal. He found that the rarefaction of the particles of theſe bodies followed the inverſe ratio of their denſity, and from thence drew the general inference. But M. Buffon, in repeating the experiment of the rarefaction of a great variety of ſolid bodies by heat, found that heat dilates them in proportion to their ſuſceptibility of alteration by fire. That is to ſay, ſtones in proportion to their calcinability, and metals in proportion to their fuſibility. Boerhaave extended this law to fluids, on no better ground than trials made with air, ſpirit of wine, and water. If he had brought mercury into the compariſon, he would not have generalized his law; for though much more denſer than either the ſpirit or the water, its dilation is greater. This experiment proves, that neither the quickneſs of becoming heated, nor the degree of expanſion, is governed by the inflammability, or by the fuſibility of the matter under conſideration. Meſſrs. Bucquet and Lavoiſier, who have made a long courſe of experiments on the dilation of fluids by heat and its progreſs, have not been able to diſcover the cauſe of the ſingular diverſity they have obſerved, and have contented themſelves with deſcribing the facts without drawing any inferences.

In addition to the laws of the rarefaction which heat produces, and which are far from being yet well underſtood, it is eſſential to know, 1. That all bodies, in paſſing from the ſolid to the fluid ſtate, or from fluidity to vapour, produce cold, as ſalts by ſolution in water, ether by evaporation, &c. 2. That fluids, capable of becoming concrete, produce heat in paſſing to the ſolid ſtate. Thus water, which freezes by being placed in a freezing mixture, never becomes ſo cold as ſpirit of wine plunged in the ſame mixture: a circumſtance, which ſhews that the water, during its converſion into ice, has given out heat ſufficient to diminiſh the effect of the mixture.

§ 4. Concerning Phlogiſton.

Beccher, ſtruck with the wonderful property certain bodies poſſeſs of producing fire, that is to ſay, heat and light, by repeated motion, or by the contact of other bodies in a ſtate of ignition, concluded that it depended on a particular principle, which he called inflammable earth. Stahl, whoſe attention was ſtrongly fixed on this doctrine, imagined that this principle was pure fire, or the matter of fire fixed in combuſtible bodies, and gave the name of phlogiſton, or the inflammable principle, to this element thus combined; in order to diſtinguiſh it from fire in action, or in a ſtate of liberty. Its properties, when in combination, are therefore very different from thoſe it poſſeſſes when at liberty; ſo that it can no longer be known by its two diſtinguiſhing criterions, heat and light. But it reſumes them when ſeparated from the bodies which confined it, and appears again with all the brilliancy and heat which accompany it when ſet free. Such was the ſimple and ſublime idea of Stahl on the nature of combuſtible bodies. It is, in fact, natural to think that ſuch matters, as by becoming once ſtrongly heated, take fire, and continue to burn till intirely conſumed, owe this property to fire concealed within them; and that combuſtion is nothing more than a proceſs by which this fire is developed. All inflammable bodies therefore, according to Stahl, contain fixed or combined fire, which is the principle of their inflammability. Hence he regarded the inflammable principle as identical in all bodies that contain it, whatever be their nature, or however they reſpectively differ from each other. Nothing more was required than the property of combuſtibility, to prove the preſence of phlogiſton in large quantity. Thus ſulphur, coal, metals, oils, phoſphorus, &c. owe their inflammability to fixed fire, and the differences of ſtructure, form, colour, conſiſtence, weight, &c. depend on the various principles with which the phlogiſton is united; this laſt being univerſally the ſame, except when by change of ſtate it becomes free or uncombined.

To arrive at a knowledge of the properties of fixed fire, or phlogiſton, Stahl made a compariſon between ſuch bodies as contain it, and others into which it does not appear to enter. He obſerved, that the firſt in general poſſeſs colour, ſmell, fuſibility, volatility, and combuſtibility; while the latter are uſually colourleſs, without ſmell, more or leſs fixed, infuſible, and more eſpecially incombuſtible. He has alſo taken notice, that bodies, manifeſtly abounding with phlogiſton, loſe the greater part of the properties common to them as ſuch, on being deprived of that principle, and have them reſtored upon being again furniſhed with phlogiſton.

It was more eſpecially from the conſideration of experiments made with ſulphur and metallic ſubſtances, that he eſtabliſhed his doctrine with ſucceſs. Metals, according to him, are compounds of peculiar earths united to phlogiſton. When they are calcined, their phlogiſton becomes diſengaged; in conſequence of which they are no longer fuſible, ductile, or inflammable. Theſe properties are reſtored when the earths are again united to phlogiſton, by heating them with oils, coal, or any other matter abounding with that principle. Sulphur is compoſed of the vitriolic acid united to phlogiſton. Its combuſtion diſengages and diſſipates the latter, the acid only remains. If this acid be treated with coals, oils, or metals, it deprives them of their phlogiſton, and again forms ſulphur, which is a coloured, odorant, fuſible, volatile, and inflammable ſubſtance.

Notwithſtanding the elegant perſpicuity of this theory, it is eaſy to point out great objections to which it is liable. If it be true, that the exiſtence of fire, as a peculiar fluid, is not at all proved even in combuſtible bodies, in the very ſtate of ignition; and if it be true, that they preſent nothing elſe to the notice of the obſerver but heat and light, how can we admit its preſence in inflammable ſubſtances in more equivocal circumſtances? Whenever we ſpeak of fire, it muſt be in a vague and inaccurate manner, if we do not confine our obſervations to light or heat. We have ſeen, that there are no deductions that ſufficiently prove the material exiſtence of heat; but every thing, on the contrary, tends to ſhew, that it is no more than a peculiar modification. Light is, therefore, the only ſubſtance, which being ſuppoſed to be the matter of fire, can be affirmed to be fixed in combination with bodies. This opinion was propoſed by Macquer. This celebrated man, after having long meditated on the nature of fire and phlogiſton, concluded that light poſſeſſed all the properties, whether it be conſidered as free and in motion, or as a principle fixed in bodies, and ſeparable by motion or agitation. This theory perfectly agrees with all the phenomena of chemiſtry.

In the explanation of a ſyſtem admitted in the ſciences, it is neceſſary at the ſame time to point out its difficulties, and ſhew its errors. Every ſyſtem hitherto offered relating to chemiſtry, has been more expoſed to errors than thoſe in any other ſcience, and that of Stahl is far from being without them. We ſhall here point out the objections which may be made againſt the doctrine of this great chemiſt, which has conſtituted one of the moſt brilliant epocahs of chemiſtry, though it has now loſt a part of its reputation.

The difficulties attending the doctrine of phlogiſton may be comprized under three claſſes. 1. The properties Stahl has attributed to this principle, are not univerſally found in thoſe bodies which he affirms to contain it. Charcoal, and in particular that of reſins, which he regards as being almoſt pure phlogiſton, is poſſeſſed neither of ſmell, volatility, or fuſibility. There are even ſome charcoals which are not very combuſtible. Diamond, a ſubſtance very infuſible, fixed, tranſparent, inodorous, is perhaps the moſt inflammable ſubſtance we know, ſince it burns totally, and without reſidue. Spirit of wine, ether, and many eſſential oils have no colour.

2. It often happens, that bodies in loſing their phlogiſton acquire the very properties Stahl commonly attributes to its preſence,

and

and which were ſcarcely obſervable in the body before. Moſt metallic bodies, by calcination, acquire a deeper colour, as may be inſtanced in cobalt, mercury, lead, iron, copper, &c.

3. Stahl, in his great attention to combuſtible bodies, from the nature of which, he endeavoured to aſcertain that of phlogiſton, has paid very little regard to the abſolute neceſſity for the preſence of air in combination; and ſeems to have forgotten how eſſential it is to that proceſs. It is in conſequence of this, that he has not foreſeen the ſtrongeſt objection that could be made to his theory; but which, however, was not propoſed by any chemiſt of his time. If combuſtion be nothing more than the diſengagement of phlogiſton, it is clearly a decompoſition, in which the inflammable body loſes one of its principles. But is it poſſible that a body, by the loſs of one of its principles, ſhould become abſolutely heavier than before? Yet it is true, that one hundred pounds of lead afford an hundred and ten of minium; and that ſulphur, by combuſtion, affords more than its own weight of vitriolic acid. And in the ſame manner, ſixteen ounces of ſpirit of wine, by being burned, affords eighteen ounces of pure water, according to the happy diſcovery of M. Lavoiſier.

The force of this objection, added to the difficulty of proving the exiſtence of phlogiſton, have induced ſome modern chemiſts to deny its exiſtence altogether. But on this ſubject it muſt be obſerved, that notwithſtanding the immenſe reſearches made of late years into the phenomena of combuſtion, the opinion, which admits the exiſtence of fire as a principle fixed in bodies, has not yet been overthrown; that the theory of Macquer, which regards light as this principle, ſatisfies all difficulties and objections; and that M. Lavoiſier, whoſe new and exact experiments would be certainly deciſive, if any were ſo, in overthrowing the doctrine of phlogiſton, has not yet adopted an opinion on the ſubject; as is clear from his admitting of fire in a ſtate of combination, though in a very different, and even oppoſite, ſenſe to that aſſumed in the doctrine of phlogiſton, as will be ſeen in the following chapter.

Since the attention of chemiſts has been directed to the neceſſity of air to combuſtion, many important diſcoveries have been made; the principal of which is, that a portion of atmoſpheric air is abſorbed by bodies that burn, and that it is this part of the air, which, becoming fixed or combined, increaſes the abſolute gravity of metals, ſulphur, phoſphorus, inflammable air, and ſpirit of wine, after their combuſtion. And it has likewiſe been diſcovered, that this augmentation correſponds accurately to the weight of the air abſorbed, ſome chemiſts, at the head of whom Meſſrs. Lavoiſier and Bucquet may be placed, have admitted a new theory, intirely founded on the abſorption of air, and wherein no mention is made of phlogiſton. This theory is directly oppoſite to that of Stahl, and is comprehended in the four following principles:

1. The bodies, called phlogiſticated by Stahl, are, according to this doctrine, bodies which have a ſtrong tendency to unite with air; a tendency which in general conſtitutes combuſtibility.

2. All the facts or circumſtances in which Stahl ſuppoſed phlogiſton to be diſengaged, conſiſt of nothing more than the entering of pure air into combination. Such are combuſtion, calcination, reſpiration, the formation of the vitriolic and phoſphoric acids by the combuſtion of ſulphur and of phoſphorus.

3. Every circumſtance, on the contrary, wherein phlogiſton enters into combination, according to Stahl, conſiſts of nothing more, in the pneumatic theory, than the diſengagement of air. Such are the production of metals effected by the reduction of metallic calces and charcoal, the decompoſition of acids by combuſtible bodies, and in particular thoſe of the vitriolic and nitrous acids by iron, charcoal, &c.

4. Every matter which Stahl ſuppoſes

to be a compound, containing phlogiſton, is regarded in this theory as a ſimple ſubſtance, which has a ſtrong affinity with pure air, and endeavours to combine with it whenever they come into contact. So that combuſtion conſiſts in a precipitation of air on the combuſtible body; and every operation, in which bodies have been thought to regain phlogiſton, is ſimply either the diſengagement of pure air, or its paſſage from one body to another.

This opinion, adopted by the late M. Bucquet, in his latter courſes of lectures, explains the greater part of the phenomena of combuſtion, calcination, and reduction of metallic calces; but it does not afford adequate reaſons for the flame which is produced by bodies in a ſtate of ignition, nor the rapid motion and other changes that attend it. M. Macquer, who muſt have been well aware of the influence of the modern diſcoveries on chemical theory, was of opinion that they do not intirely overthrow that of Stahl, and has found means to unite the pneumatic doctrine we have here explained with that of phlogiſton. After having ſhewn that pure light, ſuch as is emitted by the ſun, may be regarded as the true matter of fire, and that by admitting it as fixed in bodies, it conſtitutes the phlogiſton of Stahl; he has explained combuſtion with great perſpicuity, and in ſuch a manner, as removes all the difficulties of the ſubject. According to him, in every inſtance of combuſtion, the pure air diſengages the light or phlogiſton from inflammable bodies, and occupies its place; ſo that calcination may be regarded as the precipitation of air, and diſengagement of light. When, on the contrary, phlogiſton is reſtored to neutral ſubſtances, the matter of light ſerves to diſengage in its turn the air fixed in thoſe bodies, by which means they again reſume the metallic ſtate. In this theory, which perfectly anſwers the intention of its author, by uniting the doctrine of Stahl with that of the moderns, Mr. Macquer thinks that phlogiſton can unite with bodies even in cloſed veſſels, becauſe light, which he regards as the true phlogiſton, paſſes through glaſs veſſels, as every one knows, and even penetrates metallic or earthen veſſels when heated to ignition. This important poſition is not found in the theory of Stahl, and we ſhall hereafter be ſenſible of its influence in the explanation of a great number of phenomena in chemiſtry.

We may therefore conſider the doctrine of phlogiſton as no longer difficult. All philoſophers are acquainted with the exiſtence and phenomena of light. And we think it even a matter of aſtoniſhment, that the ingenious thought of Mr. Macquer did not occur to other chemiſts; and that Stahl himſelf did not pay attention to the influence of light in chemical phenomena. The account we have given of the effect of light on vegetables, eſſential oils, metallic calces, and ſalts, may be underſtood as conſequences of phlogiſton being imparted to thoſe bodies; and this laſt term propoſed by Stahl, and ſince admitted by every chemiſt, muſt be underſtood as ſynonymous to fixed or combined light. It is true nevertheleſs, that Mr. Lavoiſier, whoſe opinion ought to have as great influence in chemical theory as his experiments have power in accelerating its progreſs, ſeems to eſtabliſh a new theory by degrees, concerning which, in this place, we ſhall ſay a few words, as far as it relates to the doctrine of phlogiſton. He thinks that light, heat, and all the phenomena that appear in combuſtion, depend more on the air than on the combuſtible body. That the flame, which appears, is rather the light diſengaged from the pure air, than ſeparated from the combuſtible ſubſtance. The decompoſition, which, according to Stahl and Macquer, is effected in the inflammable body, he ſuppoſes to take place in the pure air, which he regards as a compound of the matter of fire and another principle; and the phlogiſton, whoſe diſengagement is the leading circumſtance, is, according to his theory, ſeparated from the pure air. We cannot, in this place, ſpeak more largely on this ingenious ſyſtem, but ſhall attend more particularly to it in our next chapter on air. It is proper however to obſerve, that the matter of fire or of heat, which Mr. Lavoiſier admits in pure air, whoſe diſengagement is ſuppoſed by him to be the cauſe of the bright flame in combuſtion, can be nothing elſe but the phlogiſton of Stahl, or the fixed light of Macquer; and that all chemiſts are of courſe agreed that it exiſts.*

§ 5. The Effects of Heat on Bodies conſidered chemically.

It has been ſeen, that one of the principal effects of heat, is the rarefaction of bodies, that is to ſay, the augmentation of their bulk, by increaſing the diſtance between the particles, and a conſequent diminution of their ſpecific gravity. This, in the ſimple, phyſical, or mechanical idea, we have exhibited in ſpeaking of rarefaction in general; but when this action is more carefully attended to, we find its other conſequences are ſuch, that it becomes of eſſential conſequence to underſtand them.

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* Nothing can be a greater indication of the infancy of a ſcience, than a variety of theories equally probable; for their exiſtence ſhews that ſome at leaſt (and perhaps many) of the moſt eſſential facts are ſtill undiſcovered. The doctrine moſt generally received in Britain is, that inflammable air is either pure phlogiſton, or contains phlogiſton nearly pure, and that its tranſitions with reſpect to pure air, are ſimilar to what the text affirms from Macquer, concerning fixed light. The great increaſe of temperature in combuſtion, is accounted for from the conſideration of the capacity of pure air for heat, which from experiment is known to be prodigiouſly great, and conſequently its temperature (page 112. note 22.) muſt be exceedingly raiſed, when its capacity becomes leſs in its fixation. Inflammable air and pure air unite in a high temperature, and form water: the heat, which maintained the aerial ſtate being given out, produces ignition. Flame conſiſts of theſe two kinds of air, in the act of uniting. T.

The firſt chemical conſideration that preſents itſelf, is, that heat, by removing the particles of bodies farther apart, diminiſhes their aggregation. The force of aggregation and the affinity of compoſition being always oppoſed * to each other, as has been ſhewn in the third chapter, it is eaſy to conceive that fire or heat ſingularly favours † combination, by deſtroying aggregation. This effect has cauſed fire to be regarded as the principal agent of the chemiſts, and they have themſelves aſſumed the title of philoſophers by fire. We ſhall ſee, however, that they avail themſelves much leſs of its aſſiſtance than they formerly did.

The action of heat conſidered under this point of view, as tending to favour combi-

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* See note, page 49.

† The ſimple removal of particles from each other, may favour combination, by enlarging the intervals through which other particles muſt paſs, in obeying the laws of affinity; and there may be many affinities too weak to act without this aſſiſtance. T..

nation, ſeems to be modified in four different manners, according to the nature of the bodies on which it exerciſes its power.

1. There are bodies which it only dilates, during the time of its continuance, without altering them in any other reſpect; theſe are called apyrous: thus it is found that rock cryſtal, ‡ expoſed to the ſtrongeſt and moſt powerful heat continued for a long time, ſuffers no alteration, either in hardneſs, tranſparency, or any other property, and comes forth from this trial as denſe and as beautiful as ever. There are few ſubſtances equally unchangeable by fire.

2. Heat entirely deſtroys the aggregation of many bodies, cauſing them to paſs from the ſolid to the fluid ſtate; ſuch bodies are called fuſible. There are different degrees of fuſibility, from that of platina, which is exceedingly difficult to melt, to that of mercury, which in our climate is always fluid. This fuſibility, carried to the extreme, is volatility. A body is volatilized, or riſes into the atmoſphere, when it paſſes from the ſtate of liquidity, by a high degree of rarefaction, to that of an elaſtic fluid. Being then lighter than the atmoſpheric air, it aſcends till condenſed by cold. Bodies poſſeſſed of this property, are ſaid to be volatile. Thoſe which do not poſſeſs it are called fixed. There are many gradations be-

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‡ It has been melted by flame, urged by a ſtream of dephlogiſticated air. T.

tween fixity and volatility. It ſeems indeed that there are no bodies abſolutely fixed, and that they are only relatively ſo with reſpect to our fires, but would riſe at greater heats than at preſent we know how to excite. The ſame obſervation applies alſo to fuſibility. The cauſe why rock cryſtal cannot be fuſed, is ſimply, that we cannot excite a ſufficient degree of heat. The infuſibility and fixity of bodies is therefore merely comparative amongſt each other, and with reſpect to our fires.

This eſſential property of volatility muſt be well diſcriminated from another kind, which is only apparent. The current of heated air, or exploſions of flame, may raiſe bodies in a ſtate of minute diviſion, though not volatile in themſelves. Thus the calx of zink is raiſed by the rapid motion of the flame which is produced in burning that ſemi-metal.

3. When heat acts on bodies compoſed of two principles, one of which is volatile, and the other fixed, it ſeparates them by volatilizing the former. Theſe bodies are decompoſed without alteration; ſo that they may be compounded again, and all their properties made to re-appear by uniting them. This ſeparation of conſtituent parts, is the true analyſis. In order that this analyſis may take place, it is a neceſſary condition that the fixed, as well as the volatile

ſubſtance be unalterable by the heat applied; for in this caſe only can the principles be again combined as before. But as it ſeldom happens, that bodies are compoſed of two ſimple principles, or that the heat can be regulated, ſo as to ſeparate more compounded principles without changing them, it is eaſy to conceive, that the number of bodies thus acted on by heat, is very ſmall. This is the reaſon why chemiſts make leſs uſe of fire in their operations than they did formerly. Subſtances decompoſable by fire, without alteration, are certain mineral matters, ſuch as cryſtallized ſalts, and ſolutions of neutral ſalts.

4. If the bodies expoſed to heat be compoſed of ſeveral principles, both fixed and volatile, the volatile principles combine together, as do alſo the fixed; ſo that the decompoſitions afford new products, which cannot form the original compound by reunion. This is the falſe or complicated analyſis; and bodies thus acted on by heat, are ſaid to be decompoſable with alteration.

The greateſt number of natural ſubſtances are of this kind; becauſe they are compoſed of too great a number of principles to admit of the action of heat, without new combinations taking place, as well as decompoſitions. Thus we find, by expoſing a piece of wood, or other vegetable matter, to the action of heat, the water, the ſalts, the oils, and the principle of ſmell, which are all volatile, unite together, and conſtitute a coloured, ſaline phlegm, of a ſtrong ſmell, together with brown or red oils, which did not exiſt in that form in the vegetable; at the ſame time that the earth, the fixed ſalts, and the colouring matter combine together, and produce a new ſubſtance, called coal. Every part is therefore changed by the action of the heat, and the phenomena announce a falſe and complicated analyſis, whoſe reſults would miſlead chemiſts, if they were not aware of its uncertainty and inſufficiency. It is certain that art cannot produce again any vegetable ſubſtance by mixture of the phlegm, ſalts, oil and coal obtained by an analyſis of this kind, becauſe the principles it affords have ſuffered very conſiderable changes. It is unfortunate that the greater number of bodies are ſubject to this kind of change by heat. Every animal and vegetable ſubſtance, and a great quantity of mineral matters, belong to this claſs; and for that reaſon chemiſts have recourſe to other methods of examining them, as will be hereafter ſhewn.

Thus far we have ſpoken only of a ſtrong heat, ſuch as is commonly applied in the different operations of art; but a low degree of heat, long continued, produces in the operations of nature a great number of phenomena, which the chemiſt ought to attend

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to, and endeavour to underſtand. The vibrations excited by the preſence of heat, in the ſolid parts of bodies, and the rarefaction and agitation produced in the fluids, keeps up a continual inteſtine motion, which by degrees changes the ſtructure of the former, and ſenſibly alters the conſiſtence, colour, taſte, and, in a word, the intimate nature of the latter. This is the general idea we may form of the exiſtence and effect of the chemical operations that take place in natural bodies, of the ſpontaneous decompoſition and re-combination of minerals, with the cryſtallization, ſolution, and formation of ſalts that take place in the interior parts of the globe we inhabit. It is to the powerful agency of heat likewiſe that we muſt recur, to account for the alterations of which the bodies of vegetables and animals are ſuſceptible, the motion of the ſap, the mild fermentation which produces maturation or ripeneſs in fruits, the formation of oils, of the ſpiritus recta, or of mucilages and of the colouring principle, the compoſition of animal fluids, their decompoſition, ſucceſſive changes and putrefaction. All theſe important phenomena are produced by chemical operations; and the heat diffuſed over our globe is the governing principle. Our preſent intention is ſufficiently anſwered, by the tranſient view we have taken of this common ſource of motion, life, and death.

We have here given a ſketch of the ſubject, and ſhall endeavour, in the following ſheets, to exhibit its parts with preciſion and accuracy.

§ 6. Concerning Fire, conſidered as a Chemical Agent, and the Method of applying it to Bodies.

The different changes produced in bodies by heat, are employed by chemiſts in decompoſing or combining bodies. The firſt circumſtance to be attended to, is to have an exact meaſure of the degrees of heat neceſſary to effect the changes, of which the matters under examination are ſuſceptible. The degrees of heat are generally conſidered under two principal diviſions; one comprehending thoſe under the temperature of boiling water, and the other ſuch as are above that temperature. The ſcale of the thermometer ſerves to diſtinguiſh the former; the latter, for the greateſt part, can be eſtimated only from the fuſibility of different ſubſtances.

Diviſions of Heat below the Boiling Water Point.

The firſt diviſion extends from 45 deg. to 60 deg. of Fahrenheit.* This temperature favours putrefaction, vegetation, ſlow evaporation, &c. It is not commonly uſed in chemiſtry, becauſe not conſiderable enough; except in certain macerations made during winter, or for the cryſtallization of ſaline mixtures after due evaporation.

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* Reaumur's ſcale is uſed in the original. T.

The ſecond diviſion extending from about 68 to 80, continues to promote putrefaction. It excites the ſpirituous fermentation in ſaccharine liquors, and facilitates evaporation, and the ſlow cryſtallization which follows. This is the ordinary heat of temperate climates. It is uſed for digeſtions, ſaline ſolutions, fermentations, &c.

The third diviſion lies between the 88th and 100th degrees of the thermometer. In this temperature the acid fermentation is beſt carried on, and plants are ſucceſsfully dried for practical uſe. It is uſed for certain ſaline ſolutions, and to promote fermentations.

The fourth diviſion is at, or near, the temperature of about 145 deg. It is called the mean degree of heated water, and is that of the veſſels called balneum mariæ. It deſtroys the organization of plants, and volatilizes the lighteſt parts of plants, eſpecially the ſpiritus rector. It is uſed in the diſtillation of vegetables and animal matters, whoſe phlegm and principle of ſmell are intended to be ſeparated.

The water temperature of boiling water, or 212 deg. is uſed in the extraction of eſſential oil.

Diviſions of Heat above Boiling Water.

The firſt diviſion melts ſulphur, burns organized matter, or gives a low red heat to glaſs veſſels.

The ſecond extends from the fuſion of the ſofter metals, ſuch as lead, tin, or biſmuth, to that of the ſofter kinds of glaſs.

The third diviſion may be conſidered as including the fuſion of metals of a middle conſiſtence, ſuch as zink, regulus of antimony, ſilver and gold.

The fourth ſerves to bake porcelain, and fuſes the more refractory metals, ſuch as cobalt, copper, iron, &c.

The laſt and higheſt of all is found in the focus of the burning glaſs. This extreme heat calcines, burns, and vitrifies, in a very ſhort time, all bodies ſuſceptible of ſuch a change.*

Though theſe diviſions above boiling water are determined by phenomena well known to chemiſts, their admeaſurement has not the deſired preciſion. An inſtrument capable of indicating with exactneſs the degrees employed in theſe operations, would be an acquiſition of great value and importance. We are aſſured that ſuch an inſtrument has been conſtructed in England. It conſiſts of a very acute angled cone, on which a ring of the ſame matter is occaſionally placed. The contraction of the dimenſions of the cone by heat, cauſes the ring to ſink to a poſition nearer the baſe, according to its intenſity. This ingenious inſtrument is yet unknown in France.[†]

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* The effects of heat are greater, when the flame of a candle or lamp is urged by a blow-pipe, than in any furnace, and greater than in the focus of the beſt burning lens, if dephlogiſticated air be uſed. A large field for experiment is open, by combining the effects of both, namely, the ſolar focus, and the ſtream of dephlogiſticated air. T.

The heat required in chemical operations, is produced by the combuſtion of charcoal, or common mineral coal. For this purpoſe, various furnaces of different forms are conſtructed, according to the purpoſe they are intended to anſwer. Such are the furnace for digeſtion, for fuſion, the reverberating furnace, the wind furnace, the cupelling furnace; and it is poſſible, by a ſkilful attention to various particulars, to conſtruct a furnace capable of anſwering the intentions of every kind. On this ſubject the chemical dictionary of Macquer may be conſulted, where the author deſcribes a peculiar and very uſeful furnace of his own invention: alſo the chemiſtry of Beaumé, the Lithogeogneſia of Pott, the Journal de Phyſique of the Abbé Roſur, in which the deſcription of many furnaces, conſtructed by various chemiſts, may be found. The flame of oil and ſpirits of wine is ſometimes employed in furnaces adapted to that purpoſe.

[†] I do not know whether the inventor of this valuable inſtrument (J. Wedgwood, Eſq.) ever thought of the contrivance of the cone; but the method he deſcribes in the Philoſophical Tranſactions for 1782, is certainly much preferable. Small pieces of clay ſlightly baked, are formed accurately to a ſtandard ſize. Theſe contract by the heat, and their dimenſions are then meaſured, by ſuffering them to fall gently between two graduated rulers, inclined to each other in a ſmall angle. The greater the contraction, the farther they go before they ſtop, and this contraction aſcertains the greateſt heat the clay has ſuffered. Theſe inſtruments are ſold by the inventor in Greek-Street, London. T.

The manner of communicating heat to bodies in the various chemical proceſſes, likewiſe deſerves to be conſidered. If the combuſtible matter itſelf be applied to the ſubſtance itſelf, or the veſſel immediately containing it, the operation is ſaid to be performed by a naked fire. If any ſubſtance be placed between the fire and the veſſel containing the matter under examination, the interpoſed ſubſtance is called a bath. Hence the names balneum mariæ, or water bath, ſand bath, cinder bath, metallic bath, &c.

The form of the veſſels employed in the treatment of bodies by fire, and the different phenomena preſented by the matter expoſed to its action, have occaſioned a conſiderable number of operations to be diſtinguiſhed by particular names. Such as roaſting, calcination, fuſion, reduction, vitrifaction, cupellation, cementation, ſtratification, rectification, concentration, digeſtion, infuſion, decoction, lixiviation. Theſe operations performed by the aſſiſtance of fire, conſtitute the principal part of the chemical nomenclature, of which we ſhall proceed to give a ſhort account.

Roaſting is a proceſs by which mineral matters are divided, ſome of their principles being volatilized, and others changed, ſo as to prepare them for other operations, to which this may be regarded as preliminary. Minerals are ſubjected to this, in order to ſeparate their ſulphur or arſenic, and to render them more pulverable or friable. In the ſmall way this is done in crucibles, or capſules of earth or iron, and generally with acceſs of air. Sometimes it is performed in cloſed veſſels, for which purpoſe two crucibles are uſually luted mouth to mouth.

Calcination is, as it were, a more advanced ſtage of the proceſs of roaſting. Minerals are by this deprived of their water, their ſalts or their phlogiſton calcareous, ſtones are thus converted into lime, and the metals into calces. The ſame veſſels are employed for this purpoſe as for roaſting.

By fuſion bodies are made to paſs from the ſolid to the fluid ſtate, in conſequence of the application of heat. Salts, ſulphur and metals, are the chief bodies ſubjected to this proceſs. Crucibles of baked clay of various kinds and figures, with metallic cones or ingot moulds, are the inſtruments chiefly uſed. Theſe laſt give the figure to the matter, which after pouring out, is then either a bar, or ingot, or a button.

In reduction or revivification, the calces of metals are reſtored to their metallic ſtate by the aſſiſtance of fire, with charcoal or other inflammable matter.

Vitrification, is the fuſion of ſubſtances capable of aſſuming the tranſparency, hardneſs, and other properties of glaſs. Vitrifiable earths with alkalis, and metallic calces, are the principal matters ſubjected to this operation.

Cupellation is the purifying of perfect metals by means of an addition of lead. This laſt, at a due heat, becomes vitrified, and promotes the vitrification and calcination of ſuch imperfect metals as may be in the mixture, ſo that theſe laſt are carried off in the fuſible glaſs which is formed, and the perfect metals are left nearly pure. The name of this operation is taken from the veſſels made uſe of, which are called cupels. Theſe are formed of the earth of bones, which, on account of its poroſity, eaſily imbibes the glaſs of lead.

Certain powders made uſe of for including particular bodies intended to be changed by their action, in cloſe veſſels, ſubjected to heat, are called cements. Thus it is that iron is cemented with powder of charcoal to convert it into ſteel; and green glaſs with plaſter or ſand, to convert it into a kind of porcelain. Cementation is a proceſs, which, in certain caſes, requires a very ſtrong heat.

Stratification is an operation nearly ſimilar to the foregoing: it conſiſts in the arrangement of various ſolid bodies in a crucible, or other veſſel capable of reſiſting the fire. Theſe are generally in the form of bars or plates, and are blended with pulverable matters, capable of altering their nature. The diſpoſition of theſe matters in beds or ſtrata, has given riſe to the name ſtratification. In this manner copper or ſilver are treated with ſulphur, in order to effect a combination. This proceſs differs from fuſion, calcination, or vitrification, only in the diſpoſition of the matters.

Detonation is peculiar to nitre, and thoſe matters of which it is a component part. It conſiſts in the noiſe produced by the exploſion of theſe ſubſtances when heated, which is greater or leſs, according to the manner and quantity of the compoſition, the ſudden or gradual application of the heat, the cloſeneſs of the veſſels, &c. Decrepitation differs from detonation in its noiſe being much leſs, and the term is uſed only with reſpect to ſuch ſalts as burſt aſunder by heat, which cauſes their water of cryſtallization to expand, and make its eſcape. It is particularly obſerved in ſea ſalt. Fulmination is a quick and ſudden detonation obſerved in fulminating gold, fulminating powder, and the combuſtion of inflammable and pure air when partially confined, or gunpowder in the like circumſtances.

The operation of volatilizing by heat, ſuch ſubſtances as are in a dry, ſolid, and often cryſtalline ſtate, is called ſublimation. The ſublimatory veſſels are of glazed earthen ware, or earthen cucurbits, with glaſs heads, or pots of earthen ware or porcelain, called aludels, arranged one above another by the inſertion of perforated necks within each other. Sulphur, arſenic, cinnabar, and many mercurial preparations, ſome vegetable matters, and in particular, camphire and flowers of benzoin, are the chief ſubſtances which are raiſed in ſublimation.

Evaporation is the volatilization of a fluid, effected by heat, in order to diminiſh the fluidity and quantity of the reſiduum, and to obtain the fixed ſalts it may hold in ſolution. In this way the water of the ſea or ſalt ſprings is driven off, and the ſalt is left. This operation is made in broad veſſels of earth, glaſs, ſilver, or other metals, according to the nature of the liquids under examination. Evaporation is performed with acceſs of air, in order that the fluid intended to be driven off may be at liberty to expand and be diſſipated, and that this may be effected more quickly by virtue of the diſſolvent power of the air on fluids in a ſtate of vapour.

Diſtillation is an operation nearly of the ſame nature, but performed in cloſed veſſels. It is intended to ſeparate the volatile from the fixed principles, by means of heat. Diſtillatory veſſels are either alembics or retorts: the former conſiſts of an inferior veſſel, called a cucurbit, deſigned to contain the matter to be examined, and having an upper part fitted to it, called the capital or head. In this laſt, the vapours are condenſed by the contact of the ſurrounding air, or in other caſes by the aſſiſtance of cold water ſurrounding the head, and contained in a veſſel, called a refrigeratory. From the lower part of the capital proceeds a tube, called the noſe, beak or ſpout, through which the vapours, after condenſation, are, by a proper figure of the capital, made to flow into a veſſel called the receiver, which is uſually ſpherical. Theſe receivers have different names according to their figure, being called mattraſſes, ballons, &c. Retorts are a kind of bottle of glaſs pottery, or metal, the bottom being ſpherical, and the upper part gradually diminiſhing into a neck, which is turned on one ſide. Diſtillation is diſtinguiſhed into three kinds, by aſcent per aſcenſum, by deſcent per deſcenſum, and ſideways per latus. Theſe diſtinctions, which are but futile, ſeem to have been taken from the form of the veſſels. Matter in a ſtate of vapour always tends to riſe; but diſtillation by alembics has been called per aſcenſion, becauſe the capital being immediately about the body, the vapours riſe in an obvious manner. The diſtillation by retorts has been called per latus, becauſe the neck of the retort comes out at the ſide of the apparatus. As to the diſtillation per deſcenſum, it is an unſkilful and ill-contrived operation, which is no longer uſed, becauſe its products are for the moſt part loſt, and thoſe which are obtained are in a foul and imperfect ſtate. It was performed by placing ſome vegetable ſubſtance on a cloth extended over the mouth of a glaſs veſſel containing ſome water; on this was laid a metal diſh containing live coals. In this way ſeveral odoriferous matters were in the ancient pharmacy, and for perfumer's uſe, diſtilled to obtain their eſſential oil. The product paſſed through the linen, and was condenſed by the water; but the greateſt part made its eſcape between the cover and the cloth. A diſtinction relating to the manner of heating bodies intended to be diſtilled is much more neceſſary to be made, than thoſe we have been ſpeaking of. The water bath, the vapour bath, the ſand bath, the bath of aſhes, conſiſt of theſe ſubſtances contained in proper veſſels over the fire. In theſe the diſtillatory veſſels are plunged, and are by that means kept at a more determined and equal heat. The naked fire is alſo uſed in diſtillations, as is alſo the flame of a lamp, or of ſpirit of wine.

Rectification is a ſecond diſtillation, in which ſubſtances are purified by their moſt volatile parts being raiſed by heat carefully managed. Thus ſpirit of wine, ether, &c. are rectified by their ſeparation from the leſs volatile and foreign matter, which altered or debaſed their properties.

Concentration is the inverſe of rectification, as it is intended to deprive fixed fluids of the water which weakens them, and is driven off on account of its greater volatility. This operation is uſed with certain acids, and particularly the vitriolic and phoſphoric, and alſo with ſolutions of alkaline and of neutral ſalts.

Digeſtion is an operation in which ſuch matters, as are intended to act ſlowly on each other, are expoſed to a ſlow heat continued for a long time. It is particularly uſed in the extraction of ſuch parts from vegetables as are ſoluble in ſpirit of wine. The ancient chemiſts held this proceſs in great eſtimation. Though this confidence ſeems well founded in conſideration of the change which, after ſtrict examination, it is found that moſt vegetable and animal ſubſtances undergo by a too powerful heat, yet it is not carried to that enthuſiaſm which the alchemiſts ſhewed in their purſuits. Theſe men, with more aſſiduity and labour than their pretended art deſerved, made digeſtions of many years duration, and believed by that means that it would be in their power to work a great number of miracles. Digeſtion is now confined to the preparing of tinctures, elixirs, cordials, and it is ſucceſsfully uſed in the extractions of vegetable or animal principles without alteration. It is likewiſe uſed to advantage in ſeveral proceſſes with minerals.

Infuſion is a proceſs well known. It conſiſts in pouring water of any required degree of temperature on ſuch ſubſtances as have a looſe texture, as thin bark, wood in ſhavings or ſmall pieces, leaves, flowers, &c. It is very uſeful in ſeparating the moſt ſoluble parts of theſe, and is applied in a great number of chemical operations.

Decoction, or continued ebullition with water, is employed to ſeparate ſuch parts of bodies as are only ſoluble at this degree of heat. It greatly alters vegetable and animal matters, coagulates the lymph, melts the fats and reſins, hardens fibrous parts; and is advantageouſly uſed in chemical operations, by ſuch as are acquainted with its effects.

Lixiviation, is the operation of diſſolving or extracting, by the help of hot water, the ſaline matter contained in the aſhes of plants, or the reſidues of diſtillation, or combuſtion, or of coals, or natural earths intended to be analyzed. This operation, therefore, nothing more than a ſolution by the aſſiſtance of heat, and does not differ from infuſion, except in the particular application of the latter to vegetable and animal matters, while the former is applied to ſubſtances that have the properties of minerals.

Such are the different operations performed in chemiſtry, by the aſſiſtance of fire: and as nothing was formerly done without this agent, this ſcience was then no more than an art, and was called Pyrotechnia. At preſent it is much leſs uſed, in conſequence of the diſcovery of more certain methods of analyſing natural ſubſtances. The action of ſolvents or menſtruums employed without the application of any heat beyond the temperature of the air, is ſufficient to effect the moſt ſingular changes, and is productive of clear and valuable deductions. This method is purſued with ſucceſs in the examination of ſalts, earth, mineral waters, vegetable matters, &c. Heat is now regarded only as an auxiliary agent, by which combinations are forwarded. As it is employed in different degrees, it would be a valuable acquiſition, if we knew how to apply it with uniform intenſity. A furnace of this kind has long been a deſideratum among chemiſts, and the manipulations of artiſts have hitherto been the only guide to the chemiſt, but it is impoſſible by this means to have the degree of preciſion ſo much to be deſired. It is ſaid, that a furnace of this kind has been conſtructed in England.* We have not yet received ſufficient information on this ſubject, to enable us to conſtruct the like; but if it be true, that ſuch a diſcovery has been made, chemiſtry will be much improved by its conſequences, and we need not doubt its ſpeedy adoption in France.

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* I know of none ſuch: but it is probable that the utility of Wedgwood's thermometer in ſhewing the variations of the higher degrees of heat, and by that means directing the artiſt to raiſe or lower his fire by the uſual methods, has given riſe to this report. T.

CHAP. VI.

Concerning the Air.

THE air is an inviſible, inodorous, inſipid, elaſtic, fluid, eaſily put in motion, capable of rarefaction and condenſation, which ſurrounds our globe to a certain height, and is called the atmoſphere. The atmoſphere is far from being intirely compoſed of ſuch air. As it receives all kinds of vapours that riſe from the earth, it may be conſidered as a chaos, whoſe parts are very difficult to be known. We ſhall ſee, however, that this inquiry has been proſecuted with conſiderable ſucceſs. Water, mineral exhalations, and the elaſtic fluids diſengaged from various ſubſtances, are continually riſing into the atmoſphere, and conſtitute, as it were, its different elements. The hiſtory of the atmoſphere conſiſts of that of its dimenſions, which is not yet aſcertained with preciſion; of the changes it experiences in weight; of the denſity, temperature, and other properties of its ſeveral ſtrata; of the effects of its rarefaction and dilatation; of winds, and of meteors. All theſe objects belong to that part of natural philoſophy which is called meteorology, and does not come within our intended limits: but as the air has a ſingular influence on all chemical phenomena, and it cannot but be of conſequence to know in what reſpects this is exerted, we ſhall here pay ſome attention to its phyſical, as well as its chemical properties.

§ 1. Concerning the Phyſical Properties of the Air.

We regard the fluidity, its inviſibility or extreme tranſparency, its want of taſte or ſmell, its gravity and its elaſticity, as the phyſical properties of air. Each of theſe requires to be attended to ſeparately.

The rarity of the air is ſuch, that it eaſily gives place to the ſmalleſt impulſe. The rarity and fluidity depend on its peculiar ſtate of aggregation; and as the ſame ſtate is found in other ſubſtances not of the ſame nature as the air of the atmoſphere, ſuch ſubſtances are termed aeriform fluids. It is the diſtinguiſhing criterion of this ſtate of aggregation, that bodies poſſeſſing it do not aſſume the ſolid ſtate by mere cold, as moſt liquid ſubſtances do. The fluidity of the air renders it ſuſceptible of thoſe rapid motions of its parts, which are called winds. It is not, however, of that ſubtlety, as to paſs through the pores of many bodies. Tranſparent ſubſtances, through which light paſſes with extreme facility, are not penetrable by air. Water, ſaline ſolutions, oils, and ſpirit of wine paſs through a great number of bodies, whoſe texture is not penetrable by air.* It has not that property by which liquids inſinuate themſelves into the pores of certain bodies, and cauſe them to expand.

Air included in veſſels is perfectly inviſible. It is not at all diſtinguiſhable by the eye from a vacuum. The great facility with which it ſuffers the rays of light to paſs through its ſubſtance, is the cauſe of this. It is conſequently colourleſs, though ſome philoſophers have thought its large maſſes were blue.†

The air has always been ſuppoſed to be perfectly inſipid. But if we attend to the conſequences of this fluid touching any bare nerve of an animal, as is the caſe in wounds and other ſimilar circumſtances, we may conclude that it has a kind of ſapidity, which habit has probably rendered inſenſible. In fact, the expoſure of wounds to the air is often attended with very acute pain. The infant, at the inſtant of its birth, ſufficiently ſhews, by its cries, the diſagreeable impreſſion this contact occaſions. This kind of acrimony in the air appears to be the cauſe of that difficulty with which wounds cicatrize, if not kept covered; and a ſimilar effect is obſervable in vegetables, whoſe bark is cut away.

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* This may be true; but it has never been proved in the moſt ſatisfactory manner; namely by the condenſer. T.

† Colourleſs fluids appear to reflect the light in the order of its reflexibility, and will therefore appear of a different tinge, accordingly as they are viewed by reflected or tranſmitted light. Thus the air is either red, orange, or yellow, according to its thickneſs, as is ſeen by the colour of the clouds illuminated at ſun-ſet by this tranſmitted light; the green, blue, indigo, and violet rays being more reflexible, are turned back, and exhibit the ſky blue. Water has a ſimilar appearance when in large maſſes. The ſea by reflection is blue, but by tranſmiſſion is red, as Halley obſerved in the diving bell. T.

The air is perfectly inodorous, and in thoſe caſes, in which a ſort of fetid ſmell is perceived, it is eaſily accounted for, by attention to the foreign bodies interſperſed through it, as miſts, vapours.‡

The weight of the air is one of the moſt valuable diſcoveries in natural philoſophy. It was not well eſtabliſhed till about the middle of laſt century, though it is affirmed, that Ariſtotle knew that || a bladder is heavier when full of air, than when empty. The ancients had no idea of the weight of the air; but attributed all the phenomena ariſing from that weight to an occult quality

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‡ The ſmell of electricity is often perceived by ſedentary people, when they go into the open air. T.

|| It is not eaſy to conjecture what may have occaſioned Boyle's miſtake in repeating this experiment. He found the bladder lighter when empty than when blown up. This certainly cannot be; for the air in the bladder acting only by its reſidual gravity in air (which is nothing) could not cauſe any preponderance. T.

they called the horror of a vacuum. The impoſſibility of raiſing water by the common pump to a greater height than thirty-two feet, engaged certain workmen to conſult the famous Galileo, who was greatly ſurpriſed at the fact. Death, in all probability, prevented his ſagacity from diſcovering the true cauſe of this, which was reſerved for his diſciple Torricellius. He was led to it by the following reaſoning: The water appeared to him to riſe in the ſucking pump ſolely in conſequence of an exterior cauſe, which by preſſure obliged it to follow the piſton. The action of this cauſe is evidently limited, as appears by its ſuſtaining a column of no more than 32 feet of water. If, therefore, it were to act on a fluid ſpecifically heavier than water, it ought to raiſe and ſuſtain to a height inverſely as its ſpecific gravity. From theſe reflections he was induced to take a tube of glaſs hermetically ſealed at one end, and thirty-ſix inches in length. He filled this with mercury, the cloſed end being downwards; then cloſing the extremity with his finger, he raiſed the other end uppermoſt, and plunged the unſealed end beneath the ſurface of a veſſel of mercury. Upon removing his finger, he obſerved the mercurial column to deſcend, till after ſeveral oſcillations its upper ſurface remained at reſt at twenty-eight inches above the ſurface of the mercury in the baſon. By comparing this height with the height of thirty-two feet, to which water is raiſed in pumps, he found it correſponded accurately to the inverſe ratio of the velocities. For the ſpecific gravity of mercury and water being in round numbers, as 14 to 1, the mercury was found to ſtand in the vacuum at only one fourteenth of the height of the water. It was not till after much meditation, that he ſuſpected the weight of the air to be the cauſe of the ſuſpenſion of water in pumps; and this doctrine was not incontrovertibly eſtabliſhed in France, till after the ingenious experiment of Paſcal in that kingdom.

This celebrated philoſopher imagined, that if water were ſuſtained at the height of thirty-two feet in pumps, and mercury at twenty-eight inches in the Torricellian tube by the ſole gravity of the air, the heights of theſe fluids ought to vary with that gravity; that they ought not, for example, to be the ſame on the top of a mountain and in a valley, becauſe the length of a column of the atmoſphere muſt be ſhorter, and conſequently its weight leſs in the former than in the latter caſe. In purſuance of this idea of Paſcal, M. Perrier on the 19th of September, 1648, at the foot and at the ſummit of the mountain Puits de Dome in Auvergne, made the famous experiment, which has for ever fixed the opinion of philoſophers on this ſubject. The barometer, or Torricellian tube filled with mercury, and fixed to a ſcale of thirty-four inches, divided into inches and lines, ſhewed a fall or diminution of the mercurial column equal to four inches, in aſcending from the foot of the mountain to its ſummit, which is five hundred toiſes higher. It was therefore clear, that a column of air of that length, is equal in weight to four inches of mercury; and ſubſequent experiments and inquiries concerning the changes of denſity of the ſeveral parts of the column of air, have been attended with ſuch ſucceſs, that the barometer is now one of the moſt uſeful inſtruments for meaſuring elevations.

The weight of the air has great influence on a number of phyſical and chemical phenomena. It compreſſes all bodies, and oppoſes their dilatation. It is an obſtacle to the evaporation of fluids. The water of the ſea is by this cauſe preſerved in its liquid ſtate, without which it would take the vaporous form, as we ſee in the vacuum of the air pump. The preſſure of the air on our bodies preſerves the ſtate both of the ſolids and fluids; and from the want of this due preſſure it is, that on the ſummits of lofty mountains the blood often iſſues from the pores of the ſkin, or from the lungs, and occaſions hemorrhages.

Laſtly, the air is ſtrongly elaſtic. It is capable of being very much condenſed, and ſuddenly regains its former ſtate when at liberty. A great number of facts prove the truth of this aſſertion. We ſhall here mention one or two of the moſt obvious, and concluſive. If mercury be poured into a tube in the form of the letter U, and cloſed at one end, the air in the cloſed end will contract in its dimenſions, in proportion as the quantity of mercury by which it is compreſſed is greater. The foot-ball of children, conſiſting of a bladder filled with wind, and incloſed in leather, ſhews the ſame elaſticity by its rebounding when it falls on hard bodies. The fountain by compreſſed air ſhews the ſame thing. This is a veſſel half filled with water, and air is ſtrongly compreſſed into its ſuperior part: the reaction of the air on the water forces it out to a conſiderable height through a tube. Laſtly, the wind gun, whoſe effects are well known, owes thoſe effects to the ſame property. It is eſtimated that air may be compreſſed into the 128th of its uſual volume.

Heat producing a contrary effect to that of compreſſion upon air, ſerves to ſhew, that its volume may be exceedingly augmented by the increaſe of its ſpring. When a bladder full of air is expoſed to the heat of a furnace, the air is dilated ſo as to burſt the bladder with an exploſion. This phenomenon is partly the occaſion of the burſting of chemical veſſels, which often happens where due precautions are not taken to prevent it. The abſence of the preſſure of the atmoſphere, or the total abſtraction of the circumambient air from beneath the receiver of an air pump, cauſes a bladder incloſed therein to burſt by the ſpring of the included air, which then acts without oppoſition.

From this account of the gravity and the elaſticity of the air, it may be readily inferred, that theſe properties are the leading cauſes of the numerous atmoſpherical changes, and the variations in the mercurial column in the barometer. In fact, the inferior ſtrata of the atmoſphere muſt ſuſtain the weight of the air above them, and are therefore in a ſtate of compreſſion, which diminiſhes with the greater elevation of places: and the continual change of temperature muſt alſo greatly affect the gravity of the air by augmenting or diminiſhing its elaſticity. Thus, as we have already noticed, the air is lighter on the tops of mountains than in lower regions; and it is from the conſideration of the effects of theſe and other changes, that the barometrical changes can only be accounted for. M. de Luc has laboured more aſſiduouſly and ſucceſsfully on this important ſubject, than any other philoſopher.*

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* The barometrical meaſurement of elevations has been well treated of both practically and ſcientifically by Sir George

§ 2. Concerning the Chemical Properties of the Air.

The properties we have deſcribed were formerly the only ones known, or treated of by philoſophers. But certain chemiſts, at the head of whom we may place Van Helmont, Boyle, and Hales, having perceived that air, or at leaſt a fluid poſſeſſing all its apparent properties, was obtained in the analyſis of many natural ſubſtances, adopted the opinion that this element combines with, and becomes fixed in bodies. Such is the origin of the term fixed air, which was given to the elaſtic fluids obtained in chemical operations. The early philoſophers ſuppoſed theſe fluids to be air; but the diſcoveries of Dr. Prieſtley have ſhewn, that there are many bodies which have the phyſical properties of air, though they differ from it eſſentially in many reſpects. It is, therefore, neceſſary to attend to thoſe other properties, in order to diſtinguiſh air from other aeriform fluids, which reſemble it in elaſticity and rarity. Theſe properties are chemical.

On inquiring into the characters of air, we find two which are peculiar to it, and

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George Shuckburgh and Colonel Roy in the 77th vol. of the Philoſophical Tranſactions. T.

well adapted to diſtinguiſh it from other elaſtic fluids. The one is the property of promoting the combuſtion or inflammation of bodies ſuſceptible of that proceſs; and the other is that of maintaining the life of animals that reſpire it. Let us carefully examine theſe important phenomena.

It is very difficult to give a good definition of combuſtion. It is a collection of phenomena, which certain bodies exhibit when heated with acceſs of air; the principal of which are the continuance or augmentation of heat, agitation, or inteſtine motion, the emiſſion of light, flame, and a total change of the matter burned. Great differences may be obſerved in combuſtible bodies; ſome burn briſkly with a luminous flame, as oils, wood, reſins, bitumens; others burn without ſenſible flame, as many of the metals, and charcoal, if well made; others again are conſumed ſlowly without ſenſible ignition, though with heat, as is ſeen in certain metallic matters. In all theſe caſes the combuſtion is performed; and the body, thus burned, cannot be again ſubjected to the ſame proceſs, and is called either aſhes or calx, according to the nature of the ſubſtance. The reſidue of the combuſtion is almoſt always heavier than the body itſelf was before it was burned, as is more particularly ſeen in ſuch as are fixed in the fire: but ſuch bodies, as contain volatile inflammable matter, burn with more rapidity than the former, and leave a reſidue much leſs heavy than before. Oils, &c. are of this kind. But this diſtinction reſpecting the weight of the reſidue is only apparent; for the reſidue in fact is in all caſes heavier than the body itſelf originally was. This important truth is evinced by a proper attention to the entire product of the inflammation. The fixed part of a body is not the whole reſidue ſtrictly conſidered, for the volatile parts eſcape into the air; and in ſome bodies the whole eſcapes in this manner. Theſe laſt would ſeem to be annihilated, if we were not to bring the volatile parts into our account, which is an abſurd poſition not to be maintained by inference from any phenomena. Thus we find that ſpirits of wine and ether burn without leaving any reſidue in the veſſels that contained them; but the matter they conſiſted of is volatilized and diſperſed. But if proper means be uſed to collect the product, it is found that its weight is greater than that of the original fluid. In this manner, M. Lavoiſier obtained eighteen ounces of water by burning ſixteen ounces of pure and highly rectified ſpirit of wine under a chimney adapted to the worm-pipe of a ſtill. And the ſame, no doubt, would happen with oils, reſins, &c. So likewiſe it is not to be concluded that the aſhes of wood is the true reſidue of the combuſtion. For a part of this ſubſtance is diſſipated in the air; that which is imperfectly burned, conſtituting ſoot; while another part eſcaping into the air is condenſed in the form of water, or exiſts in the form of elaſtic fluids of various kinds. It may, therefore, be taken for a general truth, that the weight of bodies is increaſed by combuſtion.

The explanation of this increaſe of weight depends intirely on another phenomenon of combuſtion, which muſt be more minutely inquired into. Combuſtion cannot take place without the acceſs of air, and is always carried on in proportion to the quantity and the purity of that fluid. This abſolute neceſſity for the preſence of air in combuſtion, was ſufficiently evident to Boyle and Hales; and each of them has propoſed his opinion on this ſubject. Boerhaave thought that the action of air conſiſted in its being applied to the ſurface of bodies, and ſeparated the particles ſucceſſively from each other. This hypotheſis does not by any means ſhew why the ſame air ſhould not eternally ſerve to maintain combuſtion. M. Morveau ſuppoſed this laſt fact to depend on the too great rarefaction the parts of the air ſuffered by heat, in conſequence of which he imagined the combuſtible body might ſuffer a compreſſion incompatible with the ſtate of combuſtion. But this explanation was offered at a time when the true cauſe was entirely unknown. M. Lavoiſier, by his valuable experiments on the calcination of metals in known and determinate quantities of air, has proved the fact obſerved long ago by the naturaliſt John Ray, that a portion of the air is abſorbed during calcination, that the metal acquires as much weight as the air loſes, and that the metallic calx really contains this portion of air, as is ſhewn by its diſengagement when mercury is reduced by the mere application of heat. Other facts have carried him ſtill farther. With Prieſtley he has obſerved, that the air which remains after calcination and combuſtion, cannot be made to ſerve for new proceſſes of the ſame kind, but that it extinguiſhes bodies on fire, ſuffocates animals, and, in a word, it is no longer air, &c.; and that the diminution is in proportion to the quantity of air abſorbed by the combuſtible body. On the other hand, the air obtained from metallic calces, is found to be three or four times as pure as that of the atmoſphere; ſince it is not only capable of maintaining combuſtion, but renders it much more rapid and perfect than ordinary air does; and a given quantity of this air will ſuffice to the perfect combuſtion of three or four times the quantity of a like body, which would be conſumed in an equal portion of atmoſpheric air. This ſingular fluid, which is obtained from mercurial calces, and exiſts likewiſe in the nitrous acid, and in nitre, has been called dephlogiſticated air, by its diſcoverer Dr. Prieſtley, who ſuppoſed it to be a portion of the air of the atmoſphere, from which the phlogiſton (which according to him always exiſts in the air) had been taken away and abſorbed by the calx of mercury, which is reduced in proportion as this elaſtic fluid is diſengaged by heat. Without inquiring at preſent into the truth of this theory, we ſhall take the liberty to obſerve, that this denomination may well be rejected, becauſe it leads to a large field of diſcuſſion; and that the names of pure air, or vital air, may with great propriety be applied to this fluid; becauſe it is the only fluid which ſerves to maintain combuſtion or reſpiration, and becauſe it is, to uſe an expreſſion of M. Lavoiſier, air in a much more eminent degree than air itſelf.

From the conſideration of the abſolute neceſſity of air to maintain combuſtion and its preſence in metallic calces, M. Lavoiſier concluded at firſt that combuſtion conſiſts in nothing more than the abſorption of pure air by the inflammable body. He regarded the air of the atmoſphere, abſtracting the water and different vapours that float therein, as a compound of two elaſtic fluids of a very different nature. The one, which is the only and true air, capable of maintaining combuſtion, by being precipitated on, and uniting with bodies, is the pure or vital air. It compoſes from a fourth to a third part of the atmoſphere. The other, which is a fluid deſtructive to animal life, and extinguiſhes fire, conſtitutes from two-thirds to three-fourths of the atmoſphere, and is called by him atmoſpheric mephitis. When a combuſtible body is ſet on fire in contact with atmoſpherical air, the portion of vital air becomes fixed in the body, and the combuſtion continues while this proceſs is going on; but as ſoon as the whole of the vital air is abſorbed, it ceaſes. The reſidue, thus deprived of one of its conſtituent parts, cannot ſerve to maintain new combuſtions; but this atmoſpheric mephitis will regain the properties it had before, if a portion of pure air obtained from a metallic calx, or from nitre, be added in the ſame quantity as was loſt by combuſtion. This ingenious theory propoſed in 1776 and 1777 by M. Lavoiſier, ſeemed to explain all the phenomena of combuſtion. It clearly accounted for the increaſe of weight in metallic calces, and the extinction of combuſtible bodies in an air already employed in maintaining combuſtion; but M. Lavoiſier has thought it neceſſary to modify it by the addition of new obſervations ſuggeſted by his numerous experiments. The very bright flame obſerved when bodies in combuſtion are either plunged in vital air, or when it is blown in a ſtream on the ſurface of a body already on fire, by the help of an ingenious apparatus that philoſopher has contrived for the purpoſe, induced him to inquire into its cauſe, and whether it might not be cauſed by the diſengagement of phlogiſton in the form of fire at liberty, according to the theory of Stahl. His attention to this inquiry was the more fixed by the conſideration that the celebrated Macquer, notwithſtanding the new diſcoveries, had not abandoned the theory of Stahl, but had connected his own theory with that of the father of chemical philoſophy. We have ſhewn, that Macquer maintained the opinion that the fixation of pure air in combuſtible bodies was performed only in proportion as phlogiſton was diſengaged; theſe ſubſtances, according to him, being transferred by double affinity.* M. Lavoiſier, obſerving that the luminous appearance of the flame we have ſpoken of, (and which too clearly evinces the preſence of light, or the matter of fire in action, to admit of controverſy,) ſeemed rather to environ or ſurround the combuſtible, than to be diſengaged from it, adopted the opinion that the matter of fire or heat is ſeparated from the pure or vital air, in proportion as the body burns and abſorbs a part of it. He now thinks, (as far as his learned converſation and certain details in his papers in the Memoirs of the Royal Academy of Sciences have given me to underſtand,) that pure air, as well as every other aeriform fluid, is compounded of a peculiar principle, and the matter of heat or fire, to which laſt it owes its aerial form; that it is decompoſed in combuſtion, one of its principles, whoſe nature he does not at preſent well underſtand, uniting with the combuſtible body, and by that means changing its nature and adding to its weight, while the matter of fire is diſengaged in the form of light. So that what Stahl attributes to the combuſtible body, M. Lavoiſier aſcribes to the pure air; it being this laſt which burns, if combuſtion be made to conſiſt in the diſengagement of fire. As to the other principle, which, when united to the matter of fire, conſtitutes pure or vital air, though M. Lavoiſier has not yet intirely diſcovered its nature, yet as it is aſcertained that it almoſt always forms acids by combining with combuſtible bodies, he has called it the oxyginous, or acidifying principle. It is this which produces the ſulphureous, vitriolic, cretaceous, arſenical, phoſphoric, &c. acids in the combuſtion of ſulphur, charcoal, regulus of arſenic, phoſphorus, &c. it being one and the ſame ſubſtance in all theſe. It is to be obſerved, that in this new theory, the pure or vital

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* See p. 146.

air

air procured from metallic calces was not contained in them completely formed, but is obtained from them, becauſe the acidifying principle combines with the matter of heat or light which paſſes through the veſſels, the calx of mercury, &c. is heated in.

Such is at preſent (Oct. 1784) the ſtate of the ſcience of chemiſtry, with regard to the nature of air, and its influence in combuſtion. We ſhall not, for our part, take any deciſive part in the theories we have explained, but ſhall adhere to the province of the hiſtorian, as in the firſt edition of our elements. It is enough that we have ſhewn the abſolute neceſſity of air in combuſtion, and its concomitant phenomena, whether they ariſe more immediately from the nature of air, or of the combuſtible body.

Reſpiration is a phenomenon very analogous to combuſtion. Like combuſtion it decompoſes the air: it can only be carried on in proportion to the quantity of pure or vital air which is preſent, and, when all that air is deſtroyed, animals periſh in the mephitic air which remains. It is a ſlow combuſtion, in which the matter of fire, whether it be derived from the pure air according to the opinion of M. Lavoiſier, or whether it comes from the animal fluids, as the theory of Macquer would affirm, does not appear under the luminous appearance of flame, but enters, as it ſhould ſeem, into a new combination, which produces heat. Moreover, this inviſible and inſenſible diſengagement of the matter of fire in reſpiration, reſembles thoſe ſlow combuſtions unattended with flame, when metals are calcined. The analogy between reſpiration and combuſtion is evident from heat being produced by the ſame means in both. This heat is communicated to the blood in its paſſage through the lungs, and is diſtributed by communication through the whole animal ſyſtem, ſo as to maintain the due degree of heat, which would otherwiſe be quickly conducted off by the atmoſphere, and ſurrounding bodies. Meſſ. Lavoiſier, and de la Place, have diſcovered a ſecond uſe of air in reſpiration, namely, to abſorb a principle that exhales from the blood, which they call the baſe of fixed air, and which, if ſuperabundant, would be very prejudicial to the vital functions.

The formation of fixed air, or cretaceous acid, which takes place in the pure or vital air breathed by animals incloſed in a proper apparatus, as was done by the two learned academicians above cited, clearly ſhews the dangerous conſequences that may ariſe from cloſe places too much crouded, as theatres, hoſpitals, priſons, the internal part of veſſels, &c. and the noxious effects, which air vitiated by reſpiration produces on perſons of delicate conſtitutions, are no longer to be wondered at.

We ſee, therefore, that two leading phenomena tend continually to vitiate and decompoſe the air which ſurrounds our globe. Theſe are combuſtion and reſpiration. This fluid would ſoon be rendered unfit for the maintenance of theſe natural proceſſes, if there were not other phenomena capable of reſtoring vital air to the atmoſphere, in the place of that which is continually abſorbed and loſt. We ſhall ſee, in the third part of theſe elements, that vegetables poſſeſs very extended organs, deſtined by nature to pour forth this vital air into the atmoſphere, when the rays of the ſun act upon them. Water itſelf appears to perform the ſame office, as we ſhall explain more largely in the following chapter.

CHAP. VII.

Concerning Water.

WAter has always been regarded as an element of great conſequence in moſt natural phenomena, capable of aſſuming a great number of forms, of entering into numerous combinations, unalterable in itſelf, and recovering its firſt ſtate. But the reſearches of M. Lavoiſier have ſhewn, that water, as well as air, is formed of principles of greater ſimplicity, which may be obtained ſeparate from each other. This important diſcovery conſtitutes one of the moſt brilliant epochas of chemiſtry. We ſhall ſee, in the courſe of this chapter, the methods uſed by this celebrated chemiſt, in his analyſis of water; but we muſt firſt conſider the phyſical properties of this ſubſtance.

§ 1. Concerning the Phyſical Properties of Water.

Natural philoſophers define water to be an inſipid, ponderous, tranſparent, colourleſs, and highly fluid body, ſuſceptible of the different ſtates of aggregation, from ſolidity to that of elaſtic vapour.

It is found in almoſt every natural body: there are, notwithſtanding, many ſubſtances with which art cannot unite it, though this is continually done in nature. It is obtained from wood, and the moſt ſolid bones. It exiſts in the hardeſt and moſt compact calcareous ſtones, and forms the greater part of the fluids, and a conſiderable proportion of the ſolid parts of animal bodies. Theſe are the facts that have occaſioned it to be reckoned among the number of elements.

The naturaliſt conſiders water as exiſting in large maſſes, and filling the cavities or depreſſed places on the ſurface of the earth. Its natural hiſtory comprehends that of the ice, which is eternally exiſting on the tops of mountains, and in the polar regions, of the ſeas, lakes, rivers, and brooks, of the clouds, hail, ſnow, rain, miſts, &c. It is diſtinguiſhed into terreſtrial and atmoſpheric waters, and its motion or tranſitions become a ſubject of meteorological inquiry. It ſucceſſively paſſes from the ſurface of the globe into the atmoſphere, and from the atmoſphere to the mountains, where it is condenſed into ſtreams that are the origin of ſprings and rivers, by which it directs its courſe to the grand reſervoir, the ſea. When we attend to the phenomena of this immenſe body of water, and obſerve its agitation by winds, its libratory motion or alternate riſe and fall on the coaſts called the tides, and its currents; when we perceive the effects of theſe and other motions, by which mountains are gradually formed, harbours in ſome places deſtroyed, inundations produced in others, and other coaſts again left dry; when we behold iſlands riſing from the bottom of the ſea, and others ſubmerged; we cannot but acknowledge that water is one of the moſt powerful agents in nature. If we tranſport ourſelves in imagination into the vaſt receſſes of the interior parts of the earth, we ſhall again meet this element acting in ſilence in the formation of ſalts and cryſtals, and depoſiting them in the clefts of the rocks. Theſe great ſubjects form a part of the natural hiſtory of water; but they cannot be properly explained, till the phyſical and chemical properties of this ſubſtance have been treated of.

The moſt ſtriking property of water is, its quality of aſſuming the ſeveral ſtates of ſolidity, fluidity, or vapour. Let us conſider each of theſe modifications.

Concerning Water in the State of Ice.

Ice ſeems to be water in its natural ſtate. For the natural ſtate of a body chemically conſidered, is that in which it has the ſtrongeſt poſſible aggregation. But as water is moſt abundantly found in the fluid ſtate, this laſt has been conſtantly regarded as the natural ſtate of water.

The formation of ice is attended with ſeveral concomitant circumſtances, which well deſerve to be conſidered.

1. A heat of ſome degrees is produced in water by the act of freezing, as is always the caſe when a fluid body becomes ſolid. A thermometer plunged in water beginning to freeze will indicate ſome degrees of temperature above the freezing point, though another thermometer placed in open air ſufficiently cold to freeze water, will always ſtand either at the freezing point,or below it. It follows, therefore, that a portion of the heat

which was fixed in the liquid water is diſengaged when it becomes connected into a ſolid; and accordingly we find the ſpecific heat of ice inferior to that of water. The ſame heat is obſervable in the cryſtallization of ſalts.

2. The acceſs of air favours the production of ice. Water in a well cloſed veſſel freezes very ſlowly; but if the veſſel be opened, it freezes much more quickly, and ſometimes in the inſtant of expoſure to the contact of the air. This phenomenon is ſimilar to that which happens in the cryſtallization of ſalts. Solutions of ſalts in cloſed veſſels exhibit a ſudden cryſtallization when uncovered.

3. A ſlight degree of agitation likewiſe accelerates this formation, in which reſpect alſo we find a ſimilitude between this and the cryſtallization of ſalts. By agitating certain ſaline ſolutions which do not uſually afford cryſtals, it is ſometimes found that they are by that means produced. We have often ſeen this in ſolutions of nitre, and of calcareous marine ſalt. Theſe analogies between the formation of ice and of ſaline cryſtals, prove that the former is obtained by a true cryſtallization.

4. Ice ſeems to have a greater bulk than the water had before it was frozen, and even breaks, by its expanſion, the veſſels in which it is formed. It is not, however, the water

itſelf which has acquired a greater volume in this caſe, but the air which is ſeparated from the water during congelation, is the true cauſe of the increaſe of bulk.*

The following are the Properties of Ice.

1. When ſlowly formed, its cryſtals have the figure of needles croſſing each other at an angle of 60 to 120 degrees, according to the obſervation of M. Mairan. Sometimes its cryſtallization takes a determinate and regular form. M. Pelletier, the ſcholar of D'Arcet, and member of the college of Pharmacy, obſerved in a piece of fiſtulous ice, cryſtals in the form of flat quadrangular priſms terminated at the ends by dihedral pyramids, though with great varieties. If, on the contrary, water in a conſiderable maſs be frozen ſuddenly, it forms only an irregular ſolid, in the ſame manner as it happens when ſaline liquids are too much evaporated and cooled ſuddenly.

2. Its conſiſtence is ſuch, that it may be reduced to duſt ſo ſmall as to be driven by the wind. In very cold climates the ice is ſo hard that it is cut like ſtones, and has been employed in the conſtruction of edifices.

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* The difficult queſtion concerning the expanſion of water by freezing, is not yet well reſolved. If it depended on the excluded air, it might perhaps be poſſible, by proper management, to obtain ice more denſe than water. T.

We are aſſured that even cannons have been bored out of ice, which have been charged with powder, and diſcharged ſeveral times before they melted.

3. Its elaſticity is very ſtrong, and much more remarkable than that of fluid water. Every one knows that a ball of ice thrown on a hard ſurface rebounds in the ſame manner as other ſolids.

4. It has a lively taſte approaching to cauſticity. The impreſſion of ice on the ſenſe of feeling is univerſally known. Phyſicians employ it as a tonic or diſcuſſive matter externally applied.

5. Its ſpecific gravity being leſs than that of water, it ſwims on the ſurface. This phenomenon, as we have already obſerved, ariſes from a great quantity of air interpoſed between its parts. The property of expanſion by freezing, is common to many other bodies, ſuch as butter, tallow, wax, &c.

6. Its tranſparency is leſs than that of water, in conſequence of the bubbles of air which it contains, at leaſt in ſuch maſſes as are not regularly cryſtallized. This may be eaſily ſeen by an attentive examination of a piece of ice, and if the cavities be opened under water, the air is diſtinctly ſeen to iſſue out in bubbles.

7. It melts at ſome degrees of temperature above 0° (or 32° of Fahrenheit) in Reaumur's ſcale, the liquefaction proceeding

gradually from the ſurface to the internal parts.

8. In its paſſage from the ſolid to the fluid ſtate, it produces cold. Modern chemiſts think it abſorbs heat in melting, and that the quantity abſorbed is equal to what was before given out on its congelation. All bodies capable of freezing and melting, exhibit the ſame appearance, though with variations as to the quantity of heat given out or abſorbed.

Concerning Water in the Fluid State.

The properties of fluid water are very different from thoſe of ice.

1. It has much leſs taſte than ice; and is commonly ſaid to be inſipid. Thoſe who habitually drink water, find differences, which ſhew that it has a conſiderable degree of taſte.

2. Its elaſticity is leſs, and has been denied in conſequence of the experiments of the Academy del Cimento. But the Abbé Mongez has proved, * by an intereſting ſeries of experiments, that it is elaſtic, and even ſhews that the experiment of thoſe academicians confirm the ſame, becauſe the metallic ſpheres continued to exſude drops of water

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* The compreſſibility of water was proved long ſince by John Canton, F. R. S. by experiments made under the receiver of the air pump, for which ſee the Philoſophical Tranſactions. T.

water after they had been taken from under the preſs; which could not have happened, if the water had not been diminiſhed as to its dimenſions by the compreſſion.

3. Its ſtate of liquid aggregation gives energy to its force of combination. Hence it has been called the grand diſſolvent of nature. In fact, it unites with a great number of bodies, and ſingularly favours their mutual combination.

4. It does not ſeem to unite with light, which merely paſſes through it. It is known that this laſt alters its courſe in entering into water, ſo as to paſs in a more perpendicular direction than before.

5. Heat dilates it, and converts it into the gaſeous ſtate. Its ebullition conſiſts in this paſſage from the ſtate of liquidity to that of an aeriform fluid. This phenomenon ariſes from one part of the water having taken the form of an elaſtic fluid, and becoming inſoluble in the remaining liquid. Each bubble riſes from the bottom, and breaks at the ſurface, where it is diffuſed and diſſolved in the air. We have explained the cauſe of ebullition at large in our Memoires de Chimie, publiſhed in 1784.

The weight of the atmoſphere has a ſingular influence on the ebullition of water. In proportion as this weight is greater, ſo much the more does it oppoſe the tendency in the water to aſſume the form of vapour.

This accounts for the obſervation of Fahrenheit, that the temperature of water in a ſtate of ebullition is not always the ſame. If the elevation of the mercury in the barometrical tube be attended to, it will be found that the temperature of boiling water is higher or lower according to that elevation.

This influence of the gravity of the air on ebullition muſt take place, eſpecially at different heights in the atmoſphere. So that water will, in like circumſtances, boil more eaſily, and with a leſs degree of heat on the mountains than in vallies, or on plains leſs elevated. All fluids aſſume the vaporous ſtate very readily at great heights; and for this reaſon volatile liquids, as ſpirit of wine, ether, or volatile alkali, loſe the greateſt part of their ſtrength on high mountains, as has been obſerved by philoſophers, and lately by M. de Lamanon, at the height of more than 1800 toiſes above the level of the ſea. When the weight of the atmoſphere is taken off a veſſel of water placed in the receiver of an air pump, we obſerve it to boil with great violence, and become converted into vapour, though at a temperature not exceeding 120 degrees of Fahrenheit.

A third circumſtance which influences the ebullition of water, excluſive of heat and the weight of the atmoſphere, is the humidity or dryneſs of the atmoſphere. But this property being intirely chemical, will be attended to in the next paragraph.

6. If water be heated in cloſed veſſels, with an apparatus proper to receive the vapours, theſe laſt, when condenſed, form diſtilled water. By this means it is obtained pure, and ſeparate from the ſaline and earthy matters by which natural waters are almoſt always contaminated, and which do not riſe with the vapour. Chemiſts, who require very pure water for their experiments, procure it by diſtillation. They put common water into a cucurbit of copper, lined with tin, to which a head of the ſame metal with a refrigerator is adapted, and the diſtilled water is received in very clean glaſs veſſels. It is proper to be obſerved, that in order to have very pure diſtilled water, the veſſels ſhould be uſed for no other purpoſe. The veſſels intended to diſtill quickly, ſhould be made on the new principles, that is to ſay, the cucurbit and its head ſhould be of a flattened figure, their horizontal being much longer than their vertical diameter. Water obtained by careful diſtillation thus conducted, is perfectly pure. Chemiſts formerly made uſe of ſnow or rain water; but it is at preſent well known, that theſe waters often contain foreign bodies in ſolution.

Diſtilled water has a flat or faint taſte, and cauſes a ſenſation of weight at the ſtomach; but by being ſtrongly agitated in contact with air, it acquires a lively taſte, and may be drank without inconvenience. Diſtillation makes no change in pure water, except that of depriving it of the air, which gives it that freſh and lively taſte required to make it potable. Boerhaave diſtilled the ſame water five hundred times, without obſerving any change produced in it. Some philoſophers have affirmed at different periods that water becomes changed into earth, becauſe at each diſtillation it leaves a certain quantity of earthy matter at the bottom of the veſſel. M. Lavoiſier has made experiments reſpecting this fact. Having weighed the veſſels he uſed in diſtilling water, as well as the quantity of water and the reſidue it affords, he has ſhewn that this earth is nothing but the matter of the veſſels gradually corroded by the water. *

Concerning Water in the State of Vapour.

When water is reduced to the ſtate of vapour by the action of fire, it acquires pecu-

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* In addition to theſe obſervations on fluid water, it may be obſerved, that its temperature ceaſes to increaſe when the evaporation has arrived at a certain degree of rapidity; that this ſtationary point is higher in proportion to the difficulty the vapours find in making their eſcape; that if the vapour be prevented altogether from eſcaping, as is done in the digeſter of Papin, it will acquire, by the application of heat, a temperature approaching to ignition, and will diſſolve or act on earths and other bodies, which in other caſes it does not ſenſibly affect. T.

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liar properties, which it had not in its two former ſtates of aggregation.

1. It is perfectly inviſible when received in the atmoſphere, provided the thermometer ſtands higher than 65 degrees, and the air be not already too highly charged with humidity.

2. If, on the contrary, the atmoſphere have a temperature below 55 degrees, and be charged with humidity, the vapour of water forms a whitiſh cloud, ſenſibly opake; which ariſes from the vapour not being abſorbed, or diſſolved by the humid air.

3. Its dilation is ſuch, that by the moſt accurate computation, it is found to occupy fourteen hundred times the ſpace it poſſeſſed in the fluid form.*

4. Its elaſticity is ſuch, as to produce the moſt terrible exploſions when confined. This power is uſefully employed in mechanics, of which application the engine for raiſing water, commonly called the ſteam engine, is an admirable inſtance, well known both to philoſophers and artiſts.

5. According to one of the moſt conſtant laws of the affinity of compoſition, it has a ſtronger tendency to combination in this ſtate, wherein its aggregation is the moſt feeble, than in either of the two others. Chemiſts have frequent occaſion to obſerve

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* This varies with the temperature. T.

with what rapidity water, in the ſtate of vapour, diſſolves ſalts, ſoftens mucilaginous matters, corrodes and calcines metals, &c.

6. It is perfectly diſſolved in air. When it is ſlowly depoſited out of the atmoſphere, it conſtitutes dew. This diſſolution is performed in the ſame manner as thoſe of ſalts in water, as M. Le Roi, phyſician at Montpellier, has ſhewn in an excellent diſſertation on the elevation and ſuſpenſion of water in air. Mélanges de Phyſique et de Médicine, Paris, 1771, in octavo.

7. One of the moſt ſingular phenomena reſpecting water in a ſtate of vapour, is the property it poſſeſſes of accelerating the combuſtion of oil when on fire; as is ſeen in the experiment of the eolipile applied to the enamellers lamp, or to common fires of pit coal or wood, or fats in a ſtate of inflammation, which cannot be extinguiſhed by water. Theſe phenomena induced Boerhaave to conclude that flame is, for the moſt part, compoſed of water. We ſhall preſently ſee that this happy conjecture of Boerhaave, nearly approaches to the modern diſcoveries on water; as we ſhall ſhew that this fluid increaſes the flame in combuſtion, in conſequence of its being itſelf decompoſed.

8. Laſtly, water in the form of vapour is condenſed when expoſed to a degree of cold ſome degrees above the freezing point, as is ſeen in the falling dew. Sometimes

when the cold is beneath the freezing point it is converted into ſmall cryſtals of ice. Such is the origin of thoſe rarefied incruſtations of ice formed on the internal ſurface of the glaſs in windows during intenſe froſts; and the ſame cauſe in Siberia, and other very cold climates, converts the moiſture of the breath into a kind of ſnow.

§ 2. Concerning the Chemical Properties of Water.

The great number of combinations into which water is capable of entering, is the cauſe why natural waters are very far from being pure, and always contain various foreign matters, eſpecially ſaline ſubſtances.

Water may combine with air in two different manners, 1. It may abſorb this elaſtic fluid, and become charged with it while in its liquid ſtate. The exiſtence of air in water has long ſince been diſcovered by means of the air pump; for in proportion as the air above the water is exhauſted, the eſcape of bubbles ſhews that it likewiſe contained air. By diſtillation of water in the pneumato-chemical apparatus air is obtained. When water is boiled, the firſt bubbles are cauſed by the eſcape of air, and the lively taſte no longer remains; but this laſt is reſtored by expoſure to the air, or more quickly by agitation therein. 2. The air diſſolves water, and renders it elaſtic and inviſible when it poſſeſſes a certain degree of heat; the hotter it is, the more water it will hold in ſolution. M. le Roi, has examined very minutely into the ſtate of the water in the atmoſphere. The ingenious experiments he has made, ſhew that heated air, apparently dry, when encloſed in a glaſs veſſel, depoſits, on cooling, the water it was overcharged with, which appears in drops; that this quantity is different according to the temperature of the air; that it is precipitated during the night, and conſtitutes a particular kind of dew. He even thinks, there is reaſon to conclude from theſe facts, that the variations of the weight of the atmoſphere depend in part upon this water, which abounds more or leſs, as the temperature varies.

Though the order we have adopted ſeems to require that we ſhould not yet enter into the conſideration of ſaline matters, we muſt, nevertheleſs, obſerve in this place, that water diſſolves theſe matters very readily, and always contains a certain proportion of them. Selenite and calcareous earth, in particular, are ſubſtances which communicate diſagreable and often noxious qualities to the waters of wells, brooks, and rivers. The cretaceous acid, clay, iron, and the extracts of vegetables altered by putrefaction, are likewiſe found in waters. Waters thus vitiated, are very unfit to be uſed as drink; ſuch as abound with calcarcous earth are called crude or hard water; their taſte is flat, and they produce a ſenſe of weight on the ſtomach; they retard digeſtion; ſometimes they have the effect of purgatives, and the uſe of them may even be productive of dangerous conſequences. It is therefore very neceſſary to poſſeſs the means of knowing them, of determining with what ſubſtances they are vitiated, and of extracting thoſe ſubſtances where it can conveniently be performed.

Water proper to be drank is diſtinguiſhed by the following characters: it is very clear and limpid, its tranſparency being altered by no foreign ſubſtance; it has no kind of ſmell, its taſte is lively, freſh, and in a manner penetrating; it boils readily, and without loſing its tranſparency by the ſeparation of any ſubſtance; it diſſolves ſoap, ſo as to form an homogeneous fluid without clouds or lumps; it boils leguminous vegetables without communicating hardneſs to them. On the addition of the liquids called re-agents, ſuch as oil of tartar, or the nitrous ſolutions of mercury or ſilver, it does not ſenſibly loſe its tranſparency. And, laſtly, it paſſes readily through the ſtomach and inteſtines, and promotes digeſtion. All theſe good qualities are found in the water of a ſpring or a river which paſſes through a ſandy ſoil, is agitated by a conſtant motion, and is not charged with putrefying vegetable or animal matter. It is a neceſſary condition, therefore, that no common ſewers or drains ſhould paſs into it; that its current ſhould not be impeded or rendered ſlower by obſtacles, or by the water being drained off in too great quantities; that the watering of hemp or the waſhing of clothes in ſoapy lixiviums ſhould not be performed in it, &c. &c. On the contrary, ſuch waters as ſtand without motion in ſubterraneous cavities, which come from a calcareous or gypſeous ſoil, have no real current, abound with plants and inſects, have little depth, and reſt on a muddy bottom, compoſed of putrified vegetables, poſſeſs properties, altogether the reverſe of thoſe we have pointed out as good. Their taſte is either flat or nauſeous; their ſmell mouldy or lightly putrid; their colour often green or yellowiſh, with mucilaginous or fibrous green or brown remains of vegetables floating therein; they redden vegetable blues; become turbid by boiling; form clouds with ſoap; harden pulſe by boiling; afford precipitates more or leſs abundantly by means of the re-agents; and, laſtly, they produce a ſenſe of weight at the ſtomach, paſs with difficulty through the inteſtines, and impede the action of the digeſtive powers.

To correct theſe bad qualities, ſeveral methods are employed entirely grounded on chemical or phyſical conſiderations.

1. Stagnant waters are ſet in motion by digging a canal with a proper declivity,

where the ground will admit of it; agitating them by means of mills, or cauſing them to paſs through the air in the form of jets, caſcades, &c. Theſe methods facilitate the evaporation of the noxious air and putrid ſpiritus rector the water may contain, cauſe impurities to ſubſide by uniting them into larger maſſes, and occaſion the abſorption of a proper quantity of atmoſpheric air, &c.

2. Marſhes and ſtanding waters are to be cured by carrying away the vegetable and animal matters which are ſuſceptible of putrefaction, and prevent the due courſe of ſprings, &c.

3. Water is filtered in jars or other apparatus, whoſe bottoms are covered with fine ſand and ſpunges; theſe are to be renewed from time to time. The beds of ſmall rivulets are cleared of the mud, and a proper quantity of ſand placed inſtead thereof.

4. Theſe methods purify water, by ſeparating the heterogeneous matters that float therein, but do not deprive it of the ſaline ſubſtances, nor the putrid ſpiritus rector it may contain. To ſeparate theſe, it muſt be boiled and decanted after ſubſidence, or filtrated through paper, or clear white ſand, and expoſed to the air in ſhallow earthen or ſtone veſſels. It may then be uſed for common drink without danger; for ebullition takes away the diſagreeable flavour, and cauſes a part of the ſelenite and calcareous earth to

precipitate from hard waters. Water for theſe purpoſes ſhould be kept boiling for half an hour, or till it has acquired the property of diſſolving ſoap or boiling pulſe without rendering them hard.

5. If ebullition be found inſufficient to deprive waters of the calcareous earth or ſelenite, as commonly happens when theſe matters are in great abundance, a ſmall quantity of ſalt or oil of tartar muſt be added in the boiling, or if that be not at hand, wood aſhes may be uſed. Theſe occaſion a precipitation, and the water, after decantation and expoſure to the air is perfectly wholeſome.

6. Subſtances proper to counteract or prevent the bad effects or noxious qualities of water may be added, ſuch as ſugar, honey, meal, barley, wheat, pot herbs, or aromatic vegetables. But theſe additions do not communicate the lightneſs and other good qualities of pure water, and, in fact, only ſubſtitute one taſte for another.

This account of the chemical properties of water does not extend to the conſideration of its power as an agent in combinations, into a great number of which it enters; but in many of theſe it ſuffers a ſingular alteration, which has not been till within theſe few months diſcovered, (April 1784) and which deſerves all the attention of chemiſts. It has been long known, that water, in certain caſes, favours combuſtion, as in the inflammation of oil, at great fires, &c. and ſome philoſophers have thought it might be concluded from theſe facts, that water is converted into air. It is to Mr. Lavoiſier that we are indebted for a more accurate knowledge of theſe phenomena of the nature of water. This philoſopher having remarked with Mr. De la Place, that when inflammable air is burned with pure air in cloſed veſſels, pure water is produced, (a fact which Mr. Monge obſerved, with the greateſt preciſion, in the laboratory of The School de Meziere, nearly at the ſame time with himſelf) thought it juſt to conclude, that water was formed in this experiment by the combination of pure and of inflammable air, which he regarded as its conſtituent principles. This theory of the nature of water, by which M. Lavoiſier deprived it at once of its prerogative as a ſimple body and as an element, met with ſuch oppoſition, as convinced him that the decompoſition of water was a proof neceſſary to be added to the ſynthetical examination of that ſubſtance. He therefore endeavoured to decompoſe this fluid, by preſenting to it ſuch bodies as might be expected to ſeparate one of its principles. He aſſociated himſelf with M. Meuſnier for the purpoſe of making theſe inquiries; and theſe two philoſophers read a Memoir at the Royal Academy of Sciences the 21ſt of April, 1784; wherein it is proved that water is not a ſimple ſubſtance, but is compoſed

poſed of inflammable air and pure air, which may be eaſily ſeparated from each other. To obtain them ſeparate, Mr. Lavoiſier firſt made uſe of the following proceſs: he placed in a ſmall glaſs veſſel, inverted over mercury, a known quantity of very pure diſtilled water and iron filings. The metal was gradually and ſlowly calcined, and an elaſtic inflammable fluid was collected above the mercury; the quantity of water becoming leſs in proportion, as the two phenomena were produced. After a length of time the iron may be had entirely calcined, and the water totally decompoſed; for it is this fluid, which, according to Mr. Lavoiſier, affords the air, and calcines the iron. As it is compoſed of pure air and inflammable air, the iron by degrees attracts and combines with the former, with which it forms a metallic calx, at the ſame time that it diſengages the latter. Such was the firſt experiment by which this learned chemiſt decompoſed water; but in his experiments with Mr. Meuſnier, he employed a much more ſhort and concluſive proceſs. He cauſed water to paſs drop by drop through a gun barrel, placed in a furnace, and kept at a red heat: the water in the ſtate of vapour is decompoſed by the contact of the iron; the pure air it contains becomes fixed in the iron, as is proved by the augmentation of its weight, and the ſingular alteration it undergoes; and the inflammable air ſet at liberty, paſſes ſwiftly through the gun barrel, and is received in inverted glaſſes, properly adapted at the other end. By repeating theſe experiments with all poſſible accuracy, theſe philoſophers found, that water contains ſix parts of pure air, and one of inflammable air; that the latter is nearly thirteen times as light, as atmoſpheric air, and may occupy a ſpace fifteen hundred times greater than it poſſeſſes in its aqueous combination.

Water appears to be capable of acting in the ſame manner on all combuſtible bodies, and reduces them with different degrees of facility, to the ſtate of burned bodies, affording at the ſame time inflammable air. In this manner it has been decompoſed by zink, charcoal, and oils. The experiment with this laſt mentioned ſubſtance, is made by letting water fall, drop by drop, into boiling oil, in a retort, whoſe neck is plunged in water beneath the uſual pneumated chemical apparatus; but it requires great precaution to avoid the exploſions which take place from the water riſing * in the neck of the

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* This very common and diſagreeable accident, attendent on chemical operations, is prevented by Mr. Babington, of Guy's Hoſpital, by a ſimple and ingenious contrivance. The part of the apparatus plunged in the water, is made of a conſiderable diameter, and is immerſed to ſuch a depth, that the ſubſidence of the external ſurface of the water is ſufficient to ſuffer air to enter, before the internal water has riſen ſo as to reach the body of the veſſel. In caſes where

the retort, in conſequence of the vacuum formed within during the ebullition. In order to know whether a combuſtible body, as a metal or charcoal, &c. is capable of decompoſing water, nothing more is neceſſary, than to plunge it red hot into a veſſel of water, over which is inverted a glaſs veſſel likewiſe filled with the ſame fluid. The inflammable air, which is always diſengaged when water is decompoſed, will be collected under the glaſs veſſel. This is the cauſe of the bubbles produced by plunging red hot iron into water, and the inflammable air collected in that caſe, as has been obſerved by Meſſrs. Haſſenfraſt, Stouttz, and d'Hellancourt, of the Royal Mineralogical School of France. The ſame diſengagement of air, produced by the decompoſition of water, takes place when ignited charcoal is plunged therein.

Theſe are the facts lately diſcovered concerning the nature and compoſition of water. Meſſrs. Lavoiſier and Meuſnier therefore think that this fluid is compoſed of ſix parts pure air, and one inflammable air: that iron, charcoal and oils, having a greater affinity with pure air than the laſt has with inflammable air, ſeize it, and decompoſe the

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the admiſſion of atmoſpheric air would do harm, he injects phlogiſticated air, when the aſcent of the water ſhews it to be neceſſary. T.

water entirely; the inflammable air eſcaping in an elaſtic form: that water is recompoſed by burning theſe two kinds of air together, which, if carefully performed, affords a quantity equal in weight to that of the two fluids made uſe of: that water is thus produced in a great number of chemical operations; as for example, when ſpirit of wine or oils are burned under a chimney, adapted to the worm-pipe of a ſtill, whoſe other extremity is adapted to a recipient, a quantity of water is collected, which is almoſt always greater than that of the inflammable fluid made uſe of; which is occaſioned by the inflammable air of theſe liquids combining with the pure air of the atmoſphere, by which their combuſtion is maintained.

Theſe diſcoveries, and the theory theſe philoſophers have deduced from them, will no doubt conſtitute one of the moſt brilliant periods of philoſophical ſcience. But as it is of the utmoſt conſequence to examine the reſults and conſequences with all poſſible care, we think it proper to propoſe certain doubts, which we ſubmit to the conſideration of the learned inquirers, to whom we are indebted for theſe diſcoveries.

Mr. Lavoiſier, with many other philoſophers and modern chemiſts, maintain that all aeriform fluids owe their elaſticity to the matter of fire or heat which is united to them. This muſt therefore be the caſe with inflammable air; and as the decompoſition of water, and its change into inflammable air never takes place, but in conſequence of its being in contact with inflammable bodies; do not theſe contribute to the formation of the combuſtible elaſtic fluid, ſince it is as natural to admit the preſence of fixed fire or light in them, as it is to refer it to the pure air and other gaſeous ſubſtances. But this does not at all invalidate the proof that water is a compounded ſubſtance. It may not perhaps contain inflammable air, but only one of the principles that enter into the compoſition of that air. If this conjecture be allowed, it will follow that we are acquainted with no more than one of the conſtituent parts of water, namely, pure air. We ſhall ſee in the hiſtory of acids, metals, &c. that our knowledge concerning theſe bodies is nearly in the ſame ſituation. One of their principles ſeems to be unknown.

However this be determined, it is certain that water is not a ſimple body, but is capable of decompoſition, and that nature in her grand operations doubtleſs effects this more eaſily, and by various other proceſſes, as well as thoſe diſcovered by art. It is by a decompoſition of this kind that water tends to purify the atmoſphere, by emitting pure air; that large quantities of inflammable air are diſengaged from ſtagnant waters; that the atmoſphere is ſometimes ſo highly charged with this laſt, as to take fire, and exhibit luminous meteors, when the reſtoration of the equilibrium of the electric fluid produces the beginning of combuſtion; and that water contributes to the production of ſaline matters, in which pure air is always a principle. In a word, this happy diſcovery of Mr. Lavoiſier explains a prodigious number of phenomena relative to water, and its influence in the great works of nature.*

CHAP. VIII.

Concerning Earth in General.

THE ancient philoſophers entertained an opinion that there exiſts one ſimple ſubſtance, the principle of hardneſs, dryneſs, weight and fixity in bodies, conſtituting the baſe of all ſolid bodies, to which they gave the name of earth. This opinion, founded purely on abſtract philoſophical notions, has been conſtantly taught in the ſchools, and is ſtill admitted by ſome of the learned. Paracelſus, as we have ſeen, denominated all the reſidues of analyſes, earth; but chemiſts, by the advice and example of Glauber, having examined thoſe reſidues, found they were far from being pure earth ſubſtances.

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* Minutes of the hiſtory of the diſcoveries relating to the compoſition of water, and of the ſtate of our knowledge reſpecting that fluid are given in the tranſlator's preface. T.

Boerhaave, who with ſome limitation had adopted the opinion of Paracelſus, obſerved, that after all analyſes, there remained a dry, inſipid, heavy, colourleſs matter, poſſeſſing all the properties of an earth. But when the proper methods of chemical examination are applied to theſe matters, it is found that they differ greatly from each other, and that one and the ſame denomination cannot with propriety be applied to them all.

Beccher admitted three kinds of earth, as has been mentioned, in ſpeaking of principles, namely, the vitrifiable, the inflammable, and the mercurial earth. Stahl regarded the firſt of theſe as the true earthy principle, and Macquer joins him in thinking, that the vitrifiable earth ought to be conſidered as the moſt pure and ſimple.

To arrive at a proper determination on this ſubject, let us conſider what are the properties which chemiſts univerſally admit, as diſtinguiſhing the element of earth. We find ſix, namely, weight, hardneſs, inſipidity, fixity, infuſibility, and immutability. But all theſe properties are found in the earth of quartz, rock cryſtal, and vitrifiable ſtones in general, as well as in that of clays. If therefore ſeveral matters, very different from each other, have all the properties attributed in general to the element called earth, ought we to regard them as ſo many ſimple and primitive earths, or ought we to adopt the opinion of Stahl and Macquer, who obſerving the properties of earth moſt evidently in the vitrifiable, have thought proper to eſteem it as the primitive earth, and the others as modifications produced by its entering into different compounds?

Seducing as this hypotheſis may be, and however great the confidence we might place in the opinion of ſuch eminent chemiſts, we cannot think it proper to reckon the vitrifiable earth the primitive baſe of the others. 1. Becauſe this earth is not entirely the ſame nature in all the ſtones wherein Stahl and Macquer admit its exiſtence. 2. Becauſe, without having paſſed the organs of animals, it may be altered by ſaline mineral matters, ſuch as alkalis; ſo that it cannot again, by any method whatever, be reſtored to its former ſtate of purity: a character, which certainly ought not to be found in an element, whoſe nature is unchangeable. 3. Becauſe we do not find this earth pure, and poſſeſſing all its properties in any organized bodies; in which, nevertheleſs, we find water eſſential to their compoſition. 4. Becauſe we find in ſeveral ſubſtances all the properties of earthy matters, in the ſame manner as in vitrifiable earth, though not ſo intenſe. 5. Becauſe it is not at all proved, that vitrifiable earth is the baſe of other earths and ſolid matters, as ſome chemiſts ſeem to think.

Nature preſents ſeveral ſubſtances to our obſervation, which have all the properties of earths. We cannot aſcertain which is the ſimpleſt among them, becauſe they all ſeem to be equally ſo, as far as experiments have determined; and even if it were diſcovered that one of them were ſimpler than the reſt, it could not be concluded to be the elementary earth, till it was ſhewn to be the baſis of other earths, and the cauſe of coheſion and ſolidity in various compounds. We ought therefore, without deciding which is properly ſpeaking the element, to admit of different kinds of earths, and endeavour to obtain ſuch a knowledge of their properties, as will ſerve to diſtinguiſh them whenever they are met with in chemical analyſes.

Chemiſts have long admitted ſeveral kinds of earthy matters: but their firſt diviſions were vicious in many reſpects, becauſe the characters they were founded on were neither ſufficiently certain, nor numerous. Such, for example, is the diſtinction of earths into mineral, vegetable, and animal earths. For, though it is true, that the laſt fixed reſidues of vegetables, after lixiviation, are for the moſt part without ſmell, taſte, or ſolubility, theſe properties are not ſufficient to juſtify the claſſing them with earths, becauſe they are neither unalterable, infuſible, nor ſimple. The ſubſtance which forms the dry and infuſible baſe of the bones of animals, and is ſtill called by the name of earth, from its inſipidity and inſolubility, has been known for ſome years to be a true ſaline ſubſtance, as we ſhall ſhew in our hiſtory of the animal kingdom; and it may with great probability be conjectured, that the inſipid and inſoluble reſidues, after the laſt analyſis of other animal matters, are of the ſame nature as the reſidual matter of bones. The name of metallic earth given to the dry calces of the ſeveral matters from the inſipidity and inſolubility of ſome of them, does not agree with their other properties; for they are in general fuſible, and are all known to be compounded, as will hereafter be ſhewn.

Mineralogiſts, who have treated of the hiſtory of earths, have paid a greater attention to accuracy and preciſion in their claſſification than chemiſts; who have attended to them only in ſuch a general way as they thought might ſerve to advance the theory of the ſcience they cultivated. The greateſt number of modern naturaliſts, who have claſſed theſe matters, have adopted characters founded on theſe chemical properties, and by that means given much perſpicuity to the natural hiſtory of the mineral kingdom. Such are Meſſ. Wallerius, Cronſtedt, and Monnet, who have compoſed complete ſyſtems of mineralogy on this principle. No chemiſt has made a greater number of reſearches into the nature of ſtones and earths than Pott, who has given a methodical arrangement of theſe bodies, founded on the reſults of his own experiments. Much praiſe and gratitude is due from the public to M. Dietrich for his continued labours, and to Meſſ. Bergman and Bayen for their analyſes of many earthy ſubſtances. We ſhall not attempt to exhibit or compare the different ſyſtems of theſe authors, as it is not our preſent intention to write the natural hiſtory of earthy ſubſtances, but ſhall only avail ourſelves of their labours to determine how many different kinds of earths there are, chemically conſidered, and what are the diſtinctive characters of each.

Before we enter on this ſubject, we muſt obſerve, that is it proper to conſider ſtones and earths as conſtituting the ſame claſs, becauſe they are, in fact, nothing more than one and the ſame ſubſtance in a different ſtate of aggregation. Grit-ſtone, for example, is nothing more than ſand united by the force of aggregation; and ſand conſiſts of grit-ſtone, whoſe integrant parts are diſunited: both ſubſtances having preciſely the ſame chemical properties.

M. Pott has divided earths and ſtones into four claſſes, the vitrifiable, the argillaceous, the calcareous, and the gypſeous. Subſequent diſcoveries have ſhewn, that the ſubſtances formerly diſtinguiſhed by the name of calcareous earth, are true neutral ſalts, and gypſeous ſtones are alſo known to be ſaline ſubſtances. Among the four claſſes of ſtones admitted by Pott, there are only two which belong really to this genus.

Doctor Black, whoſe name diſtinguiſhes one of the greateſt periods of the improvement of chemiſtry, having examined with much care, the baſe of the Epſom ſalt, has proved that it conſiſts of a peculiar ſubſtance, which he called magneſia, and placed among the earths. All the chemiſts have aſſented to his diſcovery.

M. Bergman has diſcovered in the marmor metallicum, or heavy ſpar, a peculiar earth, which he has called terra ponderoſa, or ponderous earth.

We think, we ought to diſtinguiſh theſe two ſubſtances, from earths properly ſo called, in conſequence of reaſons which we ſhall give in the following chapters.

From various conſiderations we think, that no bodies ſhould be admitted as true earths, but ſuch as are perfectly inſipid, inſoluble, and infuſible; and that we ought to diſtinguiſh ſuch as poſſeſs theſe properties by the chemical phenomena they exhibit. We therefore admit of but two kinds of pure earths, which are equally ſimple and elementary.

The firſt is, that which conſtitutes rock cryſtal, quartz, grit-ſtone, flints, and all hard ſtones that ſtrike fire with ſteel. Its chemical character is, that it is inalterable by the ſtrongeſt fire, neither loſing its hardneſs, tranſparency, nor other properties by any heat that art can produce.* We call it vitrifiable earth, becauſe it is the only earth which forms a tranſparent glaſs by combination with alkalis.

The ſecond kind of earth, which we regard as ſimple and pure, is the argillaceous. In its ſtate of purity, it preſents the following characters. It is almoſt always opake, or at leaſt its tranſparency is never like of the vitrifiable ſtones. It is always diſpoſed in thin plates, or laminæ on each other. Though it has no more taſte than vitrifiable earth, it ſeems nevertheleſs to have a kind of action on our organs, as appears by its adheſion to the tongue. Its force of aggregation is never ſo conſiderable, as that of vitrifiable earth; whence it follows, that argillaceous ſtones are never very hard, but break by the blow of a ſteel inſtrument, without ſcratching it, or giving fire, as vitrifiable earths do. This ſmall force of aggregation renders this earth much more diſpoſed to combination, and therefore we meet with pure clay much more ſeldom than pure cryſtal or quartz. It may be readily conceived, after this obſervation,

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* F. L. Eharmann, in a treatiſe on the art of melting, by the aſſiſtance of dephlogiſticated air, printed at Straſburgh, July, 1786; affirms that he melted rock cryſtal in one minute into a ſemi-tranſparent ball full of bubbles, by flame urged by a fine ſtream of dephlogiſticated air. T.

vation, why clays are almoſt always coloured, and why there are few clays which poſſeſs the argillaceous characters in an eminent degree. Clay expoſed to the action of heat, experiences an alteration which vitrifiable earths do not. Inſtead of remaining unchanged, it hardens, and obtains an aggregation ſtronger than in its natural ſtate. It even approaches the vitrifiable earth in hardneſs and want of diſpoſition to combine, after ſuch treatment. Water has ſome action on clay, which it penetrates, and renders ſoft and ductile. That this is a kind of combination is evinced by the adheſion of theſe two ſubſtances, which is ſuch, that they cannot be ſeparated but by the action of a ſtrong heat continued for a long time. The property of clay to be ſoftened by water, and become hard by fire, is of great value in the arts. Laſtly, the property of entering into combination with a great number of ſubſtances, eſpecially diſtinguiſhes it from the vitrifiable earth. From this it is, that clay is found in a great number of compounds; and from the conſideration of this, we have ſpoken more largely of this earth; as a knowledge of its leading characters is neceſſary, in order to diſtinguiſh it in chemical operations.

Theſe two earths we have thought fit to diſtinguiſh, as they both poſſeſs the characters of elementary ſubſtances, and no chemiſt has yet ſucceeded in decompoſing them. We are not ſufficiently advanced in our knowledge concerning the origin, formation, or even the chemical properties of theſe earths, to pronounce with certain chemiſts, that the one is more ſimple than the other, and that the latter is only a modification of the former. We cannot admit, that the earth of rock cryſtal is the baſe of clay, which as far as is yet known is not the ſame ſubſtance, either attenuated, divided, or elaborated; for no chemiſt has ever converted the one into the other.

It rarely happens, that vitrifiable or argillaceous earth is found in nature in a ſtate of purity. The former alone enjoys this privilege in rock cryſtal; doubtleſs becauſe, as we have obſerved, of its great hardneſs and force of aggregation. Even this is often coloured by foreign matters. It is ſtill more frequently altered and combined with colouring matters in quartz. Argillaceous earth is yet leſs frequently found alone. The greateſt part of the earths and ſtones, to which naturaliſts have given different names, are compoſed of one or the other, or both theſe earths; or of ſaline ſubſtances, eſpecially lime, and magneſia, with metallic matters, moſt frequently iron. To obtain a conviction of this truth, nothing more is neceſſary than to caſt an eye over M. Monnet's work, in which that chemiſt ranges ſtones after their conſtituent parts. An attempt worthy of great praiſe, but which, while it ſhews the great advantages lithology may expect to receive from chemiſtry, affords at the ſame time a proſpect of the difficulties that ſtill attend the accurate claſſification of ſtones, from their chemical properties. The following chapter will be more particularly employed on this ſubject.

PART II.

PART II.

Concerning the Mineral Kingdom; or Mineralogy.

SECTION I.

Earths and Stones.

CHAP. I.

General Facts and Obſervations on Mineralogy; the Diviſion of Minerals in general, and of Earths and Stones in particular; their different Characters.

THE deſign of natural hiſtory conſiſts in the knowledge of the bodies which conſtitute our globe. The whole is full of grandeur and ſublimity; and its parts are immenſe. This ſcience comprehends all terreſtrial phenomena, from the meteoric changes of the atmoſphere, to the mutations to which the interior parts of the globe are ſubject. The ſurface of the earth, its ſeas, lakes, rivers, mountains, valleys, plains, and caverns; the animated and organized beings which dwell therein, and the inanimate matter of which they are compoſed, occupy by turns the attention of the natural hiſtorian. The man of genius is alone capable of viewing the great deſign at once in all its component parts; the ſcrupulous and indefatigable obſerver attaches himſelf to the detail. The ſeparate conſideration of the parts has produced the various branches of this ſtudy. Theſe are inexhauſtible. Laborious men have conſecrated their lives to the obſervations and deſcriptions of the habits and manners of certain inſects, and have left the ſubject ſufficiently replete with matter for the gratification of future inquirers.

The ſtudy of natural hiſtory would, therefore, be diſcouraging, on account of the immenſity of the proſpect, if the difficulties were not removed by arrangements, by which the memory is relieved, and aſſiſted. Theſe arrangements are called methods. They conſiſt in ſuch a diſpoſition of natural bodies, as places thoſe neareſt each other, which have ſimilar properties; and others remoter, as their properties differ. The claſſification thus made, ought to be founded on characters which are conſtant, obvious, and eaſy to be known.

The diviſion of bodies into three grand orders, called kingdoms, namely, the mineral, the vegetable, and the animal kingdoms, is founded on the moſt ſtriking differences of character. Though the two laſt reſemble each other in ſome of their leading properties, yet they are ſufficiently different from each other in their external form and organization, to be conſidered ſeparately.

Minerals form the maſs of the globe, or rather the external cruſt, as far as the labours of men have penetrated. They do not increaſe in volume, but by juxta poſition of parts, and the force of attraction. They are ſubject to no alteration, but ſuch as ariſes from the chemical action of ſubſtances on each other. They are called inorganized, or inanimate bodies.

Vegetables, on the contrary, grow larger by an internal force or principle. They have organs which elaborate the juices they attract from the earth, and from the air. They are ſubject to the modifications of living ſubſtances. They grow, live, and die. They produce their like by a true generation.

Laſtly, animals have more complicated organs than vegetables; their changes are more rapid; and they are much more ſubjected to the action of ſurrounding bodies, in proportion

tion to their loco-mobility, and their higher degree of ſenſibility.

That part of natural hiſtory which relates to minerals, is called mineralogy. The early naturaliſts divided minerals into a great number of claſſes. In their methodical enumeration, they admitted earths, ſands, ſoft ſtones, hard ſtones, precious ſtones, figured ſtones, ſalts, ſulphurs, pyrites, minerals, metals, &c. Thoſe who are deſirous of obſerving the ſucceſſive progreſs of mineralogy, from the time of Henckel, one of the firſt who has treated methodically on this ſubject, to that of Daubenton, whoſe claſſification is a maſter-piece of preciſion and exactneſs, may ſee the ſyſtems in ſucceſſive order collected in the Introduction to the Manuel de Mineralogiſte of Mongez, publiſhed in 1784, at Paris. The ſucceſſive periods of this ſcience are marked by the labours of Bromel, Cramer, Henckel, Wolterſtdorff, Gellert, Cartheuſer, Juſti, Lehman, Wallerius, Linneus, Vogel, Scopoli, Romé de Lille, Cronſtedt, De Borne, Monnet, Bergman, Sage; and laſtly, Daubenton, who in the preſent ſtate of the ſcience has left ſcarcely any thing to be deſired.

To obtain a knowledge of the great number of minerals which compoſe the globe, they muſt be arranged in ſeveral claſſes, diſtinguiſhed by very evident characters. We ſhall, therefore, divide them into three ſections. Under the firſt we ſhall range earths, and ſtones, which have no taſte, and do not burn when heated with contact of air; under the ſecond, ſaline matters, having more or leſs taſte, which melt in water, and do not burn; and under the third, combuſtible ſubſtances, not ſoluble in water, and exhibiting a flame more or leſs evident when expoſed to the fire with acceſs of air.

Earths and ſtones form the greateſt part of our globe, and are eaſily diſtinguiſhed from ſalts or inflammable bodies, by their inſolubility and unchangeableneſs in the fire. Their arrangement in beds, or ſucceſſive ſtrata, conſtitutes mountains or hills, and plains. In the former, they are either in ſhapeleſs maſſes, or in ſtrata inclined to the horizon. In the plains they are horizontally diſpoſed, and covered with a bed of mold fit for the vegetation of plants, which is produced by the decompoſition of the organized bodies that are formed and decay on the ſurface of the earth. The ſeveral kinds of earth are frequently diſtributed in a regular cryſtalline form in the clifts or ſubterraneous cavities. Water, which appears to have formed the greateſt part of theſe, continually attenuates them, tranſporting them from one place to another, and in general producing in them many changes. Their natural hiſtory is divided into geology and lithology; the former treats of earths, the latter of ſtones. But theſe two, as we have before obſerved, ought to be ranged in the ſame claſs; becauſe earths, if we except the ſoil formed by the reſidue of decayed organized matters, are nothing elſe but ſtones, whoſe aggregation is deſtroyed, and ſtones are formed by the union of earths.

The number of different forms of earths and ſtones being very great, and the knowledge of them of great importance to ſcience, as well as to the common applications of them to uſeful purpoſes, naturaliſts have in all ages been induced to endeavour to diſtinguiſh them by ſure and eaſy methods. The ancients had not the idea of claſſing them from their diſtinctive characters, but contented themſelves with deſcribing their general properties, and the hiſtory of the uſes they were applied to, together with their value, or the degree of eſtimation they were then held in. From this it is that the greateſt part of the ſtones deſcribed by Pliny, are not to be found or known. Modern naturaliſts, aware of the inconveniencies of this method of deſcribing ſtones, have taken another method of diſtinguiſhing them, with the intention that all future ages may underſtand their deſcriptions. It is from the external and ſenſible properties of theſe ſubſtances, that they have diſtinguiſhed them into orders, gener, and ſpecies, and have by that means rendered the ſtudy of them more eaſy and advantageous.

The external and ſenſible characters which diſtinguiſh earths and ſtones in the modern lithological methods, conſiſt in their form, their hardneſs, their internal ſtructure, or their appearance when broken, and their colour. Several naturaliſts have added to theſe ſome of their chemical characters, more eſpecially their habitudes in the fire, and with acids. We ſhall here conſider each of theſe properties, that the application of the general principles to the particular hiſtory of each genus of ſtones may be better underſtood.

§ 1. Concerning the Form or Figure of Stones, conſidered as one of their general Characters.

By the form of ſtones, is underſtood the reſpective arrangement of their ſurfaces, with relation to each other. The moſt tranſient view of a collection of ſtones in a cabinet of natural hiſtory, ſhews that ſome poſſeſs a regular geometrical figure, while others are altogether without any ſymmetry as to their form; and that this regularity is in ſome caſes found in tranſparent, and in others in opake bodies. Obſervation has demonſtrated, that ſome kinds of ſtones affect a peculiar form in their cryſtals, and that other kinds are never found but in miſ-ſhapen fragments. Many naturaliſts are of opinion that all ſtony matters have the property of taking a cryſtallized form, which is more remarkable in ſome than in others; but that all have their peculiar forms, which are ſenſible even in their ſmalleſt parts. This is the opinion of Romé de Lille, who has written a very copious and exact hiſtory of all mineral ſubſtances relative to their ſeveral cryſtallizations *. This philoſopher diſtinguiſhes the form, which ſtones and all other minerals affect, under three denominations of determinate, indeterminate, and confuſed cryſtallization, and obſerves, that there is no mineral ſubſtance, which does not come under one of theſe three claſſes. The truth is, that as many of theſe affect the ſecond and third kind of cryſtallization, which are irregular, and not eaſy to be diſtinguiſhed, we cannot avail ourſelves much of the cryſtalline form of ſtones to give them poſitive and determinate characters from this circumſtance. Many mineralogiſts have, nevertheleſs, eſtabliſhed entire ſyſtems of lithology and mineralogy on the regular external forms of the matter deſcribed. Linneus is the firſt who adopted this plan, and though he has not entirely accompliſhed the intention

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* Criſtallographie, ou Deſcription des formes propres á tous les Corps du Régne minéral, &c. Paris, 1783. 4 tom. 8vo.

tion meant to be anſwered in his methodical diviſions, he at leaſt directed the attention of obſervers to the forms of cryſtals, and opened the way to all the diſcoveries ſince made reſpecting them.

Such is the preſent ſtate of opinions relative to the influence of cryſtallography on the ſtudy of ſtones and minerals. It is very uſeful to lead us to the hiſtory of the formation of theſe ſubſtances, and may, in ſome caſes, throw great light on inquiries reſpecting their nature. It may even ſerve to diſtinguiſh them from each other; but it is not ſufficient to ſerve as the baſis of an entire ſyſtem of mineralogy, becauſe it is in reality nothing more than one of the ſeveral means, by the union of which ſuch a ſyſtem may be conſtructed. M. Romé de Lille, who has ſo greatly diſtinguiſhed himſelf by his reſearches into the forms proper to all minerals, has not availed himſelf of this alone in his claſſification of bodies, but has only examined and deſcribed thoſe minerals arranged according to their reſpective ſaline, ſtony or metallic nature, and their mutual combinations.

§ 2. Concerning Hardneſs, conſidered as a Character of Stones.

The aggregation of the parts which compoſe ſtones is ſo various, that lithologiſts have advantageouſly made uſe of it to diſtinguiſh them from each other. Some have an aggregation ſo ſtrong, and are conſequently ſo hard, that ſteel of the higheſt temper makes no impreſſion on them. Such are the precious ſtones or gems. Others yield with difficulty to the action of inſtruments; ſuch are quartz, flints, agate, hard ſandſtone, porphyry, and granite. All theſe ſtones, when ſtruck againſt a piece of ſteel, produce a great number of ſparks; which circumſtance has occaſioned them to be called ſcintillant or ſparkling. Theſe ſparks ariſe from ſmall portions of the ſteel which are ſtruck of by the ſtone, and ſuddenly ſet on fire by the ſtrong percuſſion they undergo. This heat is ſo conſiderable, that the particles are melted; ſo that when collected on white paper, and obſerved with a good magnifier, they are found to be a kind of ſemivitrified calx, ſimilar to that produced at iron forges. Stones that give fire having different degrees of conſiſtence, from gems, and rock cryſtal, to the tender ſand-ſtones, and ſiliceous breccias of modern formation, the quantity of ſparks muſt vary in the ſame proportion.

There is a great number of ſtones, whoſe aggregation is much leſs conſiderable, and which are ſoft enough to be cut and formed by ſteel inſtruments. Theſe do not give fire with ſteel, but break with different degrees of facility when ſtruck with a hard tool. The difference of conſiſtence in ſtones, which do not give fire with the ſteel, is obſervable in their other properties. Some, as for example marble and alabaſter, receive a good and uniform poliſh; others, as for example, moſt of the calcareous ſtones, are capable of an inferior or falſe poliſh, and have always a dull greaſy appearance. Some judgment may be formed of the kind of poliſh ſtones are capable of, by the appearance they exhibit when wetted; the moiſture producing the effect of a poliſh while it laſts.

It is to be noted, that many ſtones may afford ſparks, though they are not really of the claſs of ſcintillant ſtones. Theſe are produced by their being of a mixed kind, and containing fragments of ſtones ſufficiently hard to produce ſparks. Thus it is that ſeveral kinds of calcareous marble give ſparks, when ſtruck with the ſteel, in conſequence of the quartzoſe or flinty particles intermixed with their calcareous paſte.

The denſity of ſtones is neceſſarily as their ſpecific gravity. Some naturaliſts have conſidered this laſt property as very important for the claſſification of ſtony ſubſtances. M. de Buffon is of this opinion. But this character, however important for aſcertaining the natural order and formation of theſe ſubſtances, requires accurate experiments to be made, and cannot be uſed in the lithologic methods, in which facility and ſimplicity are neceſſary requiſites to guide ſtudents at their entrance into this part of natural hiſtory.

§ III. Concerning the Fracture, conſidered as a Character of Stones.

When a ſtone is broken, the newly ſeparated ſurfaces exhibit a peculiar arrangement of the integrant particles, which is different in different ſpecies. Lithologiſts call this appearance the fracture, and it affords very uſeful characters to diſtinguiſh ſtones from each other. By comparing the circumſtances which relate to the fracture of all the ſtones we are acquainted with, it is eaſy to reduce theſe fractures to ſeveral kinds.

Some, for example, break like glaſs, with a poliſhed ſurface, of a regularly curved figure, and this is called the vitreous fracture. It is obſerved in rock-cryſtal, quartz, &c.

Others preſent a ſurface clean and poliſhed, but formed of ſucceſſive undulations, reſembling thoſe obſerved on ſome ſhells. The two pieces applied together, in general fit each other very neatly. This fracture is diſtinguiſhed by the name ſhelly, or ſhell like. The undulations are of various magnitudes and appearance, and may be obſerved in ſeveral kinds of flint, jaſper, agate, or petro-ſilex.

There is another claſs of ſtones, which, when broken, exhibit at their ſurfaces an aſſemblage of projecting points, reſembling grains of ſand worn by the waters. This is called the granulated fracture. It may be eaſily obſerved in ſand-ſtone. The magnitude of theſe ſmall parts affords a number of different diſtinctions. It is with relation to this kind of fracture, that we ſay a ſtone has a fine or a coarſe grain.

Laſtly, There is a great number of ſtones, whoſe fracture ſhews them to be compoſed of many equal laminæ placed upon each other. The great part of theſe being called ſpars, the fracture is thence denominated ſparry, ſpathoſe, lamellated, or plated. Theſe laminæ differ from each other in their extent, magnitude, thickneſs, tranſparency or opacity, horizontal or oblique poſition, with reſpect to the axis and diameter of the cryſtallized ſtone, that being ſuppoſed to be placed vertically. It is the various diſpoſition of theſe in gems, calcareous or ponderous ſpars, cryſtals, &c. which ſometimes cauſes the brilliant or chatoyant * appearance obſerved in talc, and the various kinds of feldt-

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* We have no Engliſh word to expreſs this modification of light.

ſpar, as the cat's eye, the avanturine, the labrador ſtone, &c.

Some authors have made diviſions of ſtones, founded on their general appearance, together with their fracture. Cartheuſer, in 1755, publiſhed a ſyſtem of mineralogy, in which he diſtinguiſhes ſtones into lamellated, fibrous, ſolid, and granulated. But the fracture alone is inſufficient to ſerve as the baſis of a complete lithological method, but requires to be contraſted with the other characters examined in the preſent chapter. *

§ IV. Concerning Colour, conſidered as a Character of Stones.

The various colours obſervable in many ſtones, depend on combuſtible or metallic ſubſtances intimately combined with their other parts. In ſome ſpecimens the colour is uniformly ſpread through the maſs, in others it is ſeen only in certain ſpecks or points. In general the colouring parts of ſtones is accidental, or not always found in the ſame kind, and varies according to circumſtances. It is indeed true that the colour is ſufficiently conſtant in ſome ſtones, as the gems, the ſchorls and tourmalins, to ſerve as one of the indications of their

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* Vide L'Introduction à la Sciagraphie de Bergman par Mongez le jeune, page 21.

kind; but as its utility in this reſpect is very confined, it is not much applied or eſteemed by lithological writers.

Among the colours which ſerve to diſtinguiſh the ſorts and varieties of ſtones, we may diſtinguiſh the uniform, or equally diſtributed colour, accompanied with tranſparency or opacity, and ſuch as are unequally diſtributed in irregular ſpots, in veins, in points, and in bands. We muſt likewiſe pay attention to the quantity or number of colours which are ſometimes obſerved, to the number of ſix or ſeven, as in marbles. From the number and diſpoſition of the colours in theſe natural ſubſtances, it is that they have been divided into ſtones, of one, two, or three colours, variegated, ſpotted, veined, marbled, clouded, punctuated, or dotted, or bearing marks of vegetation, or other figures, &c.

§ 5. Concerning the Alteration produced by Fire, conſidered as a Character of Stones.

Some mineralogiſts, not content with examining ſtones by the exterior and ſenſible qualities, have alſo ſought for means of diſtinguiſhing them by their chemical characters. The action of fire, and the alteration they are reſpectively ſubject to from this agent, has been regarded by many lithologiſts, as a good means for obtaining a knowledge of their differences. They have obſerved that ſome, as for example, quartz, loſe their tranſparency and hardneſs, by fire, but are no otherwiſe changed; that others ſuffer no change, as for example, rock cryſtal; that others again melt, and become converted into a glaſs of a different colour, as ſhorls, zeolite, aſbeſtos, amianthus, granite; and laſtly, that others loſe their conſiſtence, and part of their weight, without melting, and at the ſame time acquire the property of ſolubility in water, as all the calcareous ſtones do. Other experiments ſhew, that ſome ſtones loſe their colour in the fire, while in others it is rendered deeper by the ſame agent. Theſe are among the general reſults of the labours of Meſſrs. Pott, D'Arcet, and many other chemiſts.

Theſe various alterations are neceſſary to be known, in order to render the hiſtory of ſtones more complete, and to ſhew their reſpective natures. They ſhew in general, that ſuch ſtones as are the leaſt changed by the fire, are the moſt ſimple; but they cannot be of any great utility in lithological methods, becauſe they require the completion of experiments, which cannot be made but in a long time, and with conſiderable ſkill. Whereas the characters beſt calculated for the claſſification of ſtones, ought to be eaſy to be known or obtained, and either founded on ſuch properties as the eye can aſcertain, or at leaſt may be collected from ſimple and ready trials or eſſays.

It is true indeed, when exterior properties are inſufficient, that we may ſometimes avail ourſelves of the change produced in ſtones by fire, by the help of the blow-pipe recommended by Bergman; but however ſimple this ingenious method may be, it always implies the neceſſity of carrying an apparatus inconvenient to travellers, and the proceſs is better calculated to be performed in a laboratory, than on a lithologic excurſion.*

§ VI. Concerning the Action of Acids conſidered as a Character of Stones.

Acids are the ſolvents moſt commonly employed. Though we have not yet ſpoken of theſe ſalts, it is neceſſary we ſhould, in this place, make a few remarks on the phenomena exhibited by ſome ſtones, when placed in contact with acids. The greater number are not at all acted on, or changed by acids; but there are ſome, which, upon a drop of nitrous acid being put on their ſurface, by means of a ſmall tube, are acted on in ſuch a manner, that the eſcape of bubbles, paſſing through the acid, occaſions an appearance reſembling ebullition. This phenomenon is called effervеſcence, and is owing to an aeriform ſubſtance ſeparated from the ſubſtance by the action of the acid. The elaſtic fluid is itſelf a peculiar acid, diſengaged by the acid dropped on the ſtone, and is the product of a true decompoſition. All calcareous ſtones containing fixed air, effervеſce by the contact of acids, and eſpecially with that of nitre, which is uſually employed in theſe eſſays. This diſengagement of an aeriform fluid, ſhews in reality, that the matter it eſcapes from is a ſaline combination; but as it is a combination poſſeſſed neither of taſte nor ſolubility in water, in any obvious degree, and as it beſides forms a great part of the external cruſt of the globe, naturaliſts have always regarded it as a ſtony ſubſtance.

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* See Bergman on the blow-pipe, at the end of his Chemical Eſſays, tranſlated into Engliſh, and publiſhed in London, 1784.

If a blow-pipe, a piece of charcoal, a ſmall ſilver ſpoon, and three ſmall phials, containing ſalt of ſoda, microcoſmic ſalt, and borax, compoſe an apparatus inconvenient to travellers, and if a proceſs, eaſy to be executed in any place where a candle can be defended from the wind, require a chemical laboratory, the author is right in diſcouraging this excellent ſmall analyſis. Very complete apparatus for this purpoſe, are ſold in London, contained in a box no larger than a book in twelves, at Brown's, bookſeller, the corner of Eſſex-ſtreet, near the Strand. T.

All ſtones may therefore be diſtinguiſhed into effervеſcent and non-effervеſcent. A ſmall phial of nitrous acid becomes, therefore, of courſe, a neceſſary article in ſuch excurſions as are made with the intention of collecting ſtones, and together with the magnifier and the ſteel, is the only inſtrument neceſſary to be uſed by the lithologiſt.

Since Bergman has recommended the examination of ſtones by fire, with the aſſiſtance of the blow-pipe, they are eſſayed likewiſe with mineral alkali, borax and fuſible ſalt of urine, which act differently on theſe matters according to their nature; and in general exhibit a fuſion more or leſs complete, accompanied with different phenomena. We ſhall ſpeak more largely on this method of analyzing ſtones, in the chapter wherein the other methods of analyzing them will be treated of.

CHAP. II.

The Lithologic Method of M. Daubenton, extracted from his Tableau de Mineralogie.

AMONG all the lithologiſts who have attempted the methodical diſtribution of ſtones, there is no one who has given diviſions more exact, more clear, or more eaſy to be underſtood, than M. Daubenton. The ſkill with which this celebrated naturaliſt has contraſted the characters of theſe ſubſtances, renders his method much more accurate and uſeful, than all thoſe hitherto propoſed. The properties he has ſelected as the baſes of his characters, are all conſtant and eaſy to be known. They conſiſt eſpecially in the regularity or irregularity of form; tranſparency, more or leſs perfect, or opacity; conſiſtence, or hardneſs, the poliſh ſtones are ſuſceptible of; form, or reſpective arrangement of integrant parts, which occaſions the vitreous, ſhell-like, granulated, lamellated, and ſpathoſe fractures; the colours, when they are not accidental; the ſurface, dull, brilliant, or chatoyant. As it would be impoſſible to improve on the preciſion and perſpicuity of the ſyſtem of M. Daubenton, we ſhall exhibit in this place his diviſion of earths and ſtones, as he has laid them before the public in his Tableau Methodique des Mineraux.*

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* Tableau mèthodique des Minéraux, ſuivant leurs différents natures, et avec des charactères diſtinctifs, apparens, ou faciles à reconnoitre; par M. Daubenton, &c. Paris, chez Demonville, Pierres, Debure, Didot l'aìné, &c. 1784, in-8. de 36 pages.

ORDER THE FIRST.

MINERALS.

SANDS, EARTHS, AND STONES.*

Theſe Subſtances do not diſſolve in Water like Salts, nor burn like combuſtible Bodies, nor have the Brilliancy of Metallic Matters.

CLASS THE FIRST.

Stones that give Fire with Steel.

Genus I. Quartz.

Cryſtalline Subſtance, fracture vitreous not lamellated.

Species I. Opake, or ſemi-tranſparent Quartz.

Varieties.
1. fat
2. grained
3. milky
4. foliated
5. cryſtallized

Species II.

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* In this place, we only give a part of the table of M. Daubenton; but when we treat of the hiſtory of ſalts and combuſtible bodies, we ſhall give the diviſions of this philoſopher,

Species II. Tranſparent Quartz, ROCK CRYSTAL.

Two Pyramids of ſix Faces, with or without a Priſm of ſix Sides (between them)

Varieties.	1. cryſtallized 2. rough 3. white 4. red. *BOHEMIAN RUBY* 5. yellow. *OCCIDENTAL TOPAZ* 6. ruddy or blackiſh. *SMOAKY TOPAZ* 7. green 8. blue. *WATER SAPPHIRE* 9. violet. AMETHYST 10. irideſcent

Species III.

ſopher, relating to theſe ſubſtances. As we have been careful to give an exact copy of his table, even ſo far as to uſe the ſame type or characters, we think it proper to ſubjoin the beginning of the advertiſement of M. Daubenton, relating to the methodical diviſion of ſtones. The following are the words of this celebrated naturaliſt.

"This table has been expoſed in manuſcript ſince the "year 1779, in the Hall of the College Royal during my "lectures; and many copies of it have been taken. I have "made various alterations, as I have received or acquired "new information reſpecting mineralogy. I have even abandoned, for the preſent, my deſign of inſerting the chemical analyſis of different minerals in my tables, as I had "begun to do, becauſe a ſufficient number has not yet been "analyſed. My principal object in drawing out this preſent

"table,

pecies III. Quartz in agglutinated fragments, Grit-ſtone, or Siliceous Grit,

granulated fracture.

Varieties.
1. hard Grit-ſtone
2. friable
3. from the Levant. *Very fine grain*
4. Filtering Stone. *Porous*
5. Glittering
6. veined
7. exhibiting figures of plants
8. coarſe grained

Species IV.

" table, has been to facilitate the ſtudy of mineralogy. The " beſt means of diffuſing the knowledge of the ſciences, is " to ſimplify their elements. Methodical diviſions promote " this intention ; for though it is impoſſible to give deſcrip- " tive characters perfectly agreeing with nature, yet ſuch as " they are, they are convenient, uſeful, and even neceſſary. " In the full explanation of my table, which I propoſe to give " in my Leçons d'Hiſtoire Naturelle, now in the preſs, I " ſhall ſhew the advantages and defects of my methodical diſ- " tribution of minerals. I ſhall only take notice in this " place, that minerals are diſtributed in this table into orders, " claſſes, ſpecies, and varieties. The diſtinctive characters " of each article of theſe methodical diviſions are printed in " Italic."

" Among the names, there are ſome in Roman capitals; " and others in Italic capitals. The former are ſuch as I " think moſt ſuitable to the things they denote ; the others

" are

Species IV. Quartz, in looſe Grains, Sand, *vitreous Surface.*

Varieties.
- 1. angular
- 2. rounded
- 3. moving
- 4. fluid

Species V. Quartz in concrete Maſſes.

Sandy and quartzoſe Pudding Stones, or breccias.

Genus II. Semi-tranſparent Stones, *vitreous fracture, ſometimes conchoidal.*

Species I. Agates.

of all colours, except the milk white, the fine red, the orange, and the green.

Varieties.
- 1. clouded
- 2. punctuated
- 3. ſpotted
- 4. veined
- 5. onyx
- 6. iriſed
- 7. preſenting the appearance of herbs
- 8. preſenting the appearance of moſs

" are ſynonymes, whoſe uſe would be attended with inconvenience, and are inſerted only to facilitate the knowledge of the things deſcribed."

Species II. Chalcedonies,

milky tranſparency

Varieties.
1. reddiſh
2. blueiſh
3. veined
4. onyx
5. iridefcent. OPALS
6. rounded and ſolid. GIRASOLS
7. rounded and hollow. HYDROPAL CHALCEDONY (Enhydre)
8. in ſtalactites
9. in ſediment
10. hydrophanes

Species III. Carnelians,

beautiful red

Varieties.
1. pale
2. punctuated
3. onyx
4. exhibiting figures of herbs
5. in ſtalactites

Species IV. Sardonyx,

orange colour

Varieties.
1. pale
2. veined
3. onyx
4. preſenting figures of herbs
5. blackiſh

Species V. Flints,

grey, white, reddiſh, blackiſh.

Varieties.
1. with tubercles
2. in layers

Species VI. The Praſeum,

green.

Varieties.
1. green
2. clouded
3. ſpotted

Species VII. Jade,

greaſy poliſh.

Varieties.
1. whitiſh
2. olive colour
3. green

Species VIII. Petroſilex,

tranſparency of wax, conchoidal fracture.

Varieties.
1. white
2. reddiſh
3. veined

Genus III. Opake Stones,

vitreous fracture, ſometimes conchoidal, or dull

Species I. Mill Stone,

more or leſs porous.

Varieties.
1. porous
2. denſe or full

Species II. Pebbles,

concentric layers.

Varieties.

1. ſpotted
2. veined
3. onyx
4. oculiform
5. preſenting the figure of herbs
6. concreted into breccias.

PUDDING STONES

Species III. Jaſper,

vitreous fracture, often dull, and without concentric layers.

Varieties.

1. green
2. red
3. yellow
4. brown
5 violet
6. black
7. grey
8. white
9. clouded
10. ſpotted
11. veined
12. onyx
13. flowered
14. univerſal
15. fragments united in breccias

Genus IV. Scintillating Spar. FELD-SPATH.

Species I. Feld-Spath, regularly cryſtallized.

Varieties.

1. in oblique (angled) priſms of four ſides
2. in ſix-ſided priſms, with ſummits of two planes
3. in ten-ſided priſms, with ſummits of two planes and four facets

Species II. Feld Spath cryſtallized confuſedly

Varieties.

1 white
2. pearl grey. FISHES EYE
3. red
4. red with brilliant ſpangles. NATURAL AVANTURINE
5. green
6. blue
7. violet
8. green and blue, by internal reflection. *LABRADOR STONE*
9. variouſly coloured, by internal reflection. CAT'S EYE

Genus V. Cryſtal Gems,

tranſparent and lamellated, not electrifiable by heat alone without friction.

Species I. Red,

Varieties.

1. Garnets *cryſtallized with* 12, 36, *or* 24 *facets. There are alſo yellow, brown, &c. garnets*

2. The

Varieties.
2. The balaſs Ruby
roſe colour, octahedral cryſtals

Species II. Red and orange

Varieties.
3. Spinell Ruby
fire colour, cryſtallized like the balaſs Ruby
4. Vermillion
cryſtallized like the garnet
5. Hyacinthe-la-belle
cryſtallized under 4 hexagonal ſides with ſummits having 4 Rhomboidal facets.

Species III. Orange coloured.

Variety
6. Hyacinths
cryſtallized like the Hyacinthe-la-belle

Species IV. Yellow.

Varieties.
7. oriental Topaz
cryſtallized in 2 Pyramids of 6 *facets*
8. Saxon Topaz
cryſtallized in priſms of eight ſides, with ſummits of 13 *faces*

Species V. Yellow and green.

Variety.
9. Peridots, *CHRYSOLITES,*
cryſtallized in a priſm of 6 *ſides, with Pyramids of* 6 *faces*

Species VI. Green.

Variety. 10. Emeralds of Peru *cryſtallized in ſix-ſided Priſms.*

Species VII. Green and blue.

Variety. 11. Aqua-marine *cryſtallized like the Saxon topaz*

Species VIII. Blue.

Variety. 12. Oriental Sapphire *cryſtallized like the oriental topaz*

Species IX. Indigo.

Variety. 13. Indigo Saphir *cryſtallized like the oriental topaz and ſapphire*

Species X. Red and violet.*

Varieties.
- 14. Syrian Garnets *cryſtallized like the garnet*
- 15. oriental Ruby *cryſtallized like the Topaz and oriental Sapphire*

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* Such Gems as are formed without colouring matter are white. Note of M. Daubenton

Genus VI.

Genus VI. Cryſtal Gems, Tourmalins,

compoſed of laminæ perpendicular to the axis of the cryſtal, electric by heat alone without friction.

Varieties.

1. Braſilian Ruby
   red in a priſm of four ſides, with pyramids of four facets
2. Braſilian Topaz
   yellow, cryſtallized like the Braſilian Ruby

Genus VII. Tourmalins,

electric by heat alone without friction, and without laminæ perpendicular to the axis of the cryſtal.

Varieties.

1. Tourmalins of Ceylon
   tranſparent, orange coloured, not much furrowed on the ſurface
2. Tourmalins of Spain
   tranſparent in a ſtrong light, orange coloured, very much furrowed
3. Tourmalins of Tyrol
   tranſverſal fiſſures in the priſm
4. Tourmalins of Madagaſcar
   SHORLS OF MADAGASCAR, opake, black
5. Lenticular Tourmalins
6. Peridots of Ceylon
   yellow and green, much furrowed
7. Peridots of Brazil
   yellow and green, much furrowed

8. Emeralds

Varieties.
- 8. Emeralds of Brazil
  green
- 9. Sapphire of Brazil
  blue †

Genus VIII. Shorls,

Not electric by heat without friction, opake cryſtals, or long green ſemi-tranſparent needles.

Species I. Cryſtallized Shorls.

Varieties.
- 1. oblique (angled) priſm of four ſides
- 2. ſix-ſided priſm
  PIERRE DE CROIX
- 3. ſix-ſided priſm, with ſummits of 2 facets, or pyramids of three or four facets
- 4. eight-ſided priſm with ſummits of two faces

Species II. In articulated fragments.

Varieties.
- 1. Spathoſe Shorl.
  ſtriæ with Spathoſe facets
- 2. in Maſſes. SHORL PASTE
  (Paſte de Shorl) brilliant points in the fracture

Genus IX. Azure Stone,

opake and blue

Varieties.
- 1. purpliſh blue
- 2. blue

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† All theſe Tourmalins, except the lenticular, are cryſtallized in nine-ſided priſms, with ſummits of three or ſix facets. Note of M. Daubenton.

CLASS THE SECOND.

Earths and Stones, which do not give Fire with Steel, and do not efferveſce with Acids.

Genus I. Clays,

when moiſt they are ductile; when dry they take a poliſh, by being ſlightly rubbed with the hand.

Species I. Clays abſolutely infuſible,

Varieties.
- 1. uſed to make pots for the glaſs-houſe
- 2. for tobacco pipes

Species II. Clays partly fuſible,

Varieties.
- 1. for porcelain
- 2. for Engliſh pottery
- 3. for ſtone-ware

Species III. Clays intirely fuſible,

Varieties.
- 1. for common pottery and delf-ware
- 2. for Fayence
- 3. for chimney tiles (Dutch tiles)
- 4. for tiles
- 5. for bricks

Genus II. Shiſtus,

argillaceous and foliated fracture.

Varieties.
1. black ſtone
2. common Shiſtus or ſlate
3. writing ſlate
4. poliſhing ſtones
5. green ſtone
6. Hone (Pierre à raſoir)
7. fragments united in breccias

Genus III. Talc,

poliſhed glittering plates, without Spathoſe fracture.

Species I. Talc in large leaves or plates.

Variety. Muſcovy talc.

Species II. In ſmall leaves.

Variety. Mica

Genus IV. Steatites,

greaſy feel, like tallow

Species I. Steatites in laminæ.

Varieties.
1. fine French chalk (de Briançon)
2. coarſe French chalk (de Briançon)

Species II. Compact Steatites.

Varieties.
1. Soap Rock (Pierre de lard)
2. Spaniſh chalk

Species III. Lapis ollaris.

Varieties.
1. Como Stone
2. foliated Lapis ollaris

Genus V.

Genus V. Serpentines,

the poliſh and colours of marble.

Species I. Opake ſerpentines.

Varieties.
- 1. ſpotted
- 2. veined

Species II. Semi-tranſparent Serpentines.

Varieties.
- 1. granulated
- 2. fibrous

Genus VI. Amianthus,

filaments not calcinable, flakes or leaves lighter than water.

Species I. Amianthus with ſoft (or flexible) fibres.

Varieties.
- 1. Amianthus with long fibres
- 2. with ſhort fibres

Species II. Amianthus, with hard (or brittle) fibres.

Varieties.
- 1. Aſbeſtos, eaſily ſeparable into parts (mur)
- 2. Aſbeſtos, difficultly ſeparable (non mur)

Species III. Amianthus in flakes or leaves.

Varieties.
- 1. foſſil leather
- 2. foſſil cork

Genus VII. Zeolite,

cryſtallized in divergent radii, or convertible into a gelly by ſolution in acids.

Species I. Cryſtallized Zeolite.

Species II. Compact Zeolite.

Varieties.
- 1. white
- 2. blue
- 3. red

Genus VIII. Fluor Spar,

fragments with triangular faces, all inclined to each other.

Species I. Fluor Spar in cryſtals.

Varieties.
- 1. octahedrons
- 2. cuneiform octahedrons
- 3. with 14 faces
- 4. cubic

Species II. Fluor Spar in irregular Maſſes.

Genus IX. Ponderous Spar,

rhomboidal fragments, the lateral faces perpendicular to the baſes

Species I. Cryſtallized Ponderous Spar.

Varieties.
- 1. in rhomboidal plates
- 2. in octahedrons with acute ſummits
- 3. in octahedrons with obtuſe ſummits
- 4. in hexagonal plates with acute ſummits
- 5. in hexagonal plates with obtuſe ſummits
- 6. in tables
- 7. in cock's combs (or lenticular)

Species II. Ponderous Spar cryſtallized confuſedly

BOLOGNA STONE.

Genus X. Heavy Stone. *TUNGSTEN,*

reſembling Fluor Spar in the form of its fragments, but much heavier; it becomes yellow in acids.

CLASS THE THIRD.

Earths and Stones which efferveſce with Acids.[*]

Genus I. Calcareous Earths.

Efferveſcence with Acids.

Species I. Compact.
Variety. Chalk.
Species II. Spongy.
Variety. Stone-marrow.
Species III. In powder.
Variety. Foſſil Flour.
Species IV. Conſiſtence of cream.
Variety. Lac lunæ.
Species V. Figured.
Variety. Congealed.

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[*] Though theſe ſubſtances are at preſent regarded by chemiſts as neutral ſalts, formed by the union of lime and cretaceous acid, we think it proper to exhibit them in this place, at the end of earthy ſubſtances, in order to give a connected view of the method of M. Daubenton. Naturaliſts, who avail themſelves of external and ſtriking characters in their diſtribution of ſubſtances, act properly in ranking them among earths. They will be conſidered under another point of view in the hiſtory of ſaline matters. Note of Mr. Fourcroy.

Genus II. Calcareous ſtones.

Colours and poliſh are bad.

Species I. Coarſe grained.

EXAMPLE.

Limeſtone from Arcueil.

Species II. Fine grained.

EXAMPLE.

The Thunderſtone.

Genus III. Marbles.

Granulated fracture, fine colours, good poliſh.

Species I. Marbles of ſix colours.

Varieties.
White, grey, green, yellow, red, and black.
EXAMPLE.
Marble from Wirtemberg.

Species II. Marbles of two colours.

Varieties.
15 in number, formed by the combinations of 6 colours, 2 together.
EXAMPLE.
white and grey.
Marble of Carrara.

Species III. Marbles of three colours.

Varieties.
20 in number, formed by the combination of 6 colours, 3 together.
EXAMPLE.
grey, yellow, and black.
Lumachello.

Species IV. Marbles of four colours.

Varieties.
15 in number, formed by the combination of 6 colours, 4 together.
EXAMPLE.
white, grey, yellow, and red.
Brocatello from Spain.

Species V. Marbles of five colours.

Varieties.
6 in number, formed by the combinations of 6 colours, 5 together.
EXAMPLE.
white, grey, yellow, red and black.
Breccias of old Caſtile.

Genus IV. Calcareous Spar.

Regular form, ſpathoſe fracture.

Species I. Cryſtallized calcareous ſpar.

Varieties.
1 obtuſe rhomboidal figure.
Iſland Spar.
2 lenticular rhomboidal figure.
3 lenticular rhomboidal figure, with 6 triangular faces.
4 acute rhomboidal figure.
5 with 12 pentagonal faces.
6 with 3 triangular faces.
7 ſix-ſided priſm.
8 ſix rhombic ſides, with 6 faces lozenge-wiſe.
9 with 12 ſcalene triangular faces.
10 with 12 faces of 4 or 5 ſides, and 6 quadrilateral facets.
11 with 6 hexagonal faces, and 12 quadrilateral facets.

Species II. Striated calcareous ſpar.

Varieties.
1 in parallel ſtriæ.
2 in divergent ſtriæ.

Genus V. Concretions.

Succeſſive coats.

Species I. Stalactitical Concretions.

Varieties.
1 in columns
2 tabular
3 reſembling alabaſter.

Species II. Concretions by incruſtation.

Species III. Concretions by ſediment.

Varieties.
1 by horizontal ſediments.
2 by rounded ſediments.

CLASS THE FOURTH.

Mixed Earths and Stones.

Mixed earths.

Genus I. Sand and clay.

pecies. Sand for founders.

Variety. Sand from Fontenai-aux-roſes.

Genus II. Sand and calcareous earth.

Genus III. Clay and calcareous earth.

Species. Marle.

Varieties.

1 marle, armenian bole.
2 marle, ſealed earth.
3 ſtone for taking ſpots out of cloth. (pierre à detacher)
4 fuller's earth.
5 porcelain earth.
6 pipe clay.
7 potter's clay (terre à fayance)
8 white marle.
9 marle in flakes.
10 marle for manure.

Mixed ſtones,

OF TWO GENERA.

Quartz and ſcintillating ſpar - -	Granitin.
Quartz and ſchorl - - - - - - -	Granitello.
Quartz and ſteatites - - - - - -	Quartzoſe ſteatites.
Quartz and mica - - - - - - -	Micaceous quartz.
Tranſparent quartz and mica -	Micaceous cryſtal.
Quartz in grit and gem ſtone - -	1 Garnet on grit ſtone. 2 Garnet in grit ſtone.

Quartz in grit and mica	Micaceous grit.
Quartz in grit and calcareous matter	1 cryſtallized grit. 2 grit in ſtalactites.
Quartz in ſand and opake ſtone	ſandy and ſiliceous breccias.
Quartz in ſand and ſchiſtus	ſcintillating ſchiſtus *hornſtone. trap.*
Quartz in ſand and zeolite	ſcintillating zeolite.
Scintillating ſpar and paſte, or cement, of ſchorl	ophites.
Semi-tranſparent ſtone, with opake ſtone	jaſperated agate, or agatized jaſper.
Schorl and mica	micaceous ſpathoſe ſchorl.
Schiſtus and mica	micaceous ſchiſtus.
Schiſtus and marble	Florence marble.
Serpentine and marble	1 green Egyptian marble. 2 ſea green marble. 3 green antique marble. 4 green marble of Suza. 5 green marble of Varalta.
Ponderous ſpar and calcareous matter	alkaline ponderous ſpar.

OF

OF THREE GENERA.

Quartz in ſand, ſhiſtus and mica	Rough wheat-ſtone.
Quartz, gem, and mica - -	garnet rock.
Quartzoſe paſte, ſcintillating ſpar in large fragments and ſchorl	porphyry.
Quartzoſe paſte, ſcintillating ſpar in large fragments and ſchorl	ſerpentine. *hard ſerpentine.*
Quartz ſchorl and ſteatites -	tuberculous rock.
Quartz, ſcintillating ſpar and ſchorl	granite.

OF FOUR GENERA.

Quartz, ſcintillating ſpar ſchorl and mica	granite.
OF SEVERAL GENERA MORE OR LESS IN NUMBER, UNITED IN BRECCIAS.	univerſal breccias.

DOUBLE BRECCIAS.

Varieties.

1 Fragments of porphyry, with a paſte of porphyry.
2 Fragments of granite, with a paſte of ſchorl.

VOLCANIC PRODUCTS.*

Genus I. Lavas, or volcanic Matters; that is to ſay, formed by Volcanos.

Species I. Porous Scoriæ.

Varieties.

1. in irregular maſſes
2. in ſtriped maſſes
3. in ſtalactical forms
4. in fragments. LAPILLO
5. in ſmall Fragments. POUZZOLANA.
6. in Powder. VOLCANIC CINDERS.

Species II. Baſaltes.

compact and ſcintillating, blackiſh cinereous fracture, with brilliant points, without ſmall plates, like thoſe of ſcintillating ſhiſtus.

Varieties.

1. in irregular maſſes
2. in round maſſes
3. in flat maſſes or tables
4. in priſms of 3, 4, 5, 6, 7, 8, or 9 ſides
5. in articulated priſms

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* M. Daubenton places the volcanic products at the end of the minerals, without ranging them under any one of the four orders that conſtitute his method. As it is uſual to ſtudy the hiſtory of thoſe ſubſtances together with ſtones, I have thought proper to adjoin them here. F.

Species III. Glaſs.

Varieties.
- 1. in detached fibres
  GLASS GALL
- 2. in agglutinated fibres
  PUMICE STONE
- 3. in compact maſſes
  VOLCANIC SCORIA.
- * *LAPIS OBSIDIANUS.*

Genus II. Volcanified Matters or Subſtances altered by the heat of volcanos appearing to have been *baked*, *calcined*, *melted*, *or vitrified.*

Species I. Granite.
II. Garnet.
III. Hyacinth.
IV. Mica.
V. Peridot.
VI. Quartz.
VII. Schorl.
VIII. Scintillating Spar.
IX. Calcareous Matters.
X. Baked Earths, Tripoli.

STONES, whoſe nature is not ſufficiently known to indicate the claſſes to which they belong.

Jargon of Ceylon,

cryſtallized in rectangular priſms, with pyramids of 4 triangular faces.

It ſeems that the name of Jargon is given to many ſtones, whoſe ſtructure is yet unknown.

Macles,

in ſquare priſms or cylinders, whoſe tranſverſe ſection preſents a blue croſs.

The Macle has been regarded as a ſchorl; but this opinion is not yet proved.

White Chryſtals,

in flattened priſms of 10 *ſides, with* 2 *ſummits of* 4 *faces, one forming a concave, and the other a convex ſolid angle.*

Violet or green Chryſtals,

rhomboidal with 2 *facets inſtead of two oppoſite angles.*

The name of Schorl has been given to theſe white, violet, and green cryſtals, though they do not appear to be of the nature of Schorls.

C H A P. III.

On Claſſification of Earths and Stones, according to their Chemical Properties.

CHemiſts, who have employed themſelves in the examination of minerals, have adopted the opinion, that it is of importance to aſcertain their mutual agreement or difference from their reſpective nature and chemical properties. And though their labours have not yet been ſufficiently diverſified and extended with reſpect to earths and ſtones, to afford a foundation for any very accurate arrangement of theſe ſubſtances on ſuch principles; it is, nevertheleſs, of importance to know the actual ſtate of the information we poſſeſs, concerning their chemical properties, and the influence thoſe properties may have on the method of claſſing them.

Among the many philoſophers who, ſince the time of Cronſtedt, have availed themſelves of the chemical properties in the claſſification of earths and ſtones, Meſſ. Bucquet, Bergman, and Kirwan, have ſucceeded the beſt, and have exhibited the moſt valuable and complete ſyſtems of lithology, conſidered chemically. The order followed by theſe three chemiſts, not being the ſame, and each poſſeſſing its own peculiar advantages, we think proper to explain them in order, at the ſame time pointing out their reſpective defects.

§ 1. The Chemical Diviſion of Earths and Stones, propoſed by M. Bucquet.

Mr. Bucquet, after having long endeavoured to unite the diſtinctive external characters made uſe of by naturaliſts in their arrangement of earths and ſtones, with thoſe which chemiſtry affords, had at length adopted a compound arrangement, which he propoſed to have uſed in his lectures, when his death deprived the ſcientific world of continuance of his labours. In the converſations I had the happineſs to enjoy with him during the lingering illneſs to which he at laſt fell a ſacrifice, I collected every detail relative to his lithologic method; and the fruits of theſe valuable converſations have been already communicated to the public in the firſt edition of this work. I ſhall here repeat the ſame, with the addition of ſuch notes as the labours of men of ſcience ſince that period have rendered neceſſary.

According to Mr. Bucquet, earths and ſtones are divided into three ſections.

The firſt comprehends the ſimple earths and ſtones; the ſecond, the compounds of thoſe ſimple bodies; and the third, the mixtures of either or both.

Simple earths and ſtones in a ſtate of purity are inſipid, dry, hard, inſoluble and infuſible ſubſtances. If ſome of theſe appear to poſſeſs theſe characters in an inferior degree, more particularly by being in certain manner fuſible, it is always to be attributed to the admixture of foreign matters. The chemical analyſis ſhews their purity, by its inſufficiency to ſeparate them into other more ſimple ſubſtances.

Compound earths and ſtones muſt be conſidered as combinations of different ſimple earths, with ſaline and metallic ſubſtances. Theſe combinations have been made in the great laboratory of nature, by means of water, or of fire. Their chemical characters are fuſibility with various kinds of glaſs, and the property of being ſeparated into other more ſimple ſubſtances by the action of ſolvents, more eſpecially acids.

Mixed earths and ſtones are known to be ſuch by the eye. They are ſeen to be compoſed of an irregular aſſemblage of different ſtones or earths, either ſimple or compound. It may readily be conceived that this irregular mixture muſt be mechanically ſeparated into its parts before the chemical analyſis can be proceeded on, which muſt be done by the examination of each kind by itſelf.

SECTION I.

Simple Earths and Stones are divided into four Orders.

ORDER I. VITREOUS STONES.

They poſſeſs extreme hardneſs and perfect tranſparency; their fracture is vitreous; they give fire with the ſteel; and the action of heat alters neither their tranſparency nor their hardneſs.

This firſt order contains two genera; rock cryſtal, and the vitreous precious ſtones.

Genus I. ROCK CRYSTAL.

Rock cryſtal exhibits all the characters of vitreous precious ſtones, in the moſt eminent degree. It is diſtinguiſhed from the following genus by its fracture, which is ſimilar to that of glaſs.

Its various kinds may be diſtinguiſhed

1. *With reſpect to their form.*

Species.

1. Solitary hexahedral cryſtals, with two hexahedral pyramids. According to the Abbé Rochon, they produce the diviſion of light uſually called double refraction.

2. Hexahedral cryſtals in groups, with one or two points.
3. Tetrahedral, dodecahedral, flattened, &c. cryſtals. Theſe are always hexahedral cryſtals, whoſe facets are varied and ſingular.
4. Rock cryſtal, in maſſes; from Madagaſcar. It has not the property of double refraction.

2. *With reſpect to colour.*

5. Reddiſh rock cryſtal.
6. Smoaky cryſtals.
7. Black cryſtals.
8. Yellow cryſtals.
9. Blue cryſtals.
10. Green cryſtals.

3. *With reſpect to accidental events.*

11. Hollow rock cryſtal.
12. Containing water.
13. One cryſtal included within another (emboités).
14. Rounded; pebbles from the Rhine.
15. Encruſted with metallic calces
16. In gæodes.
17. Containing amianthus.
18. Containing Schorl.
19. Encruſted with pyrites.

Their formation by water is proved

1. By their tranſparency.
2. By the form of ſmall cryſtals.
3. By the incloſure of one cryſtal in another.

4. By their including ſubſtances alterable by fire.

Theſe ſubſtances are cut and poliſhed into the form of vaſes and into toys.

Genus II. VITREOUS PRECIOUS STONES.

The precious ſtones placed under this diviſion have all the characters of rock cryſtal, and more particularly its unchangeableneſs by fire. Though this arrangement may ſeem an inverſion of the natural order, and Bergman has aſſured us, that he has found theſe ſtones to conſiſt of ſeveral matters combined together; yet in their hardneſs, tranſparency, and habitudes in the fire, they greatly reſemble rock cryſtal. They differ from it, however, in their ſuperior hardneſs, more lively and clear colour, and in their fracture, which is lamellated. The chemical difference which exiſts between all precious ſtones, more eſpecially as far as relates to the alterations produced in them by fire, induced M. Bucquet to ſeparate them from each other, and to include them reſpectively in ſuch orders of ſtones as they appeared to reſemble the moſt.

The following four precious ſtones are diſtinguiſhed from the reſt, by the appellation vitreous.

Species.

1. Oriental topaz.
2. Hyacinth.
3. Oriental ſapphire.
4. Amethyſt.

M. Daubenton always regarded this laſt as a quartz cryſtal.

Order II. Quartzoſe Stones.

They have leſs hardneſs and tranſparency than the foregoing. Their fracture is vitreous, and they ſtrike fire with ſteel. Heat cauſes them to loſe their hardneſs and tranſparency, and reduces them to a white and opake* earth. We ſhall range four genera of ſtones under this order.

Genus I. QUARTZ.

Has all the preceding characters.

Species.

1. Tranſparent quartz, cryſtallized in hexagonal pyramids, without priſms of any ſenſible length, or with very ſhort priſms.
2. Tranſparent quartz in maſſes.

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* It is on account of their different habitudes in the fire, that M. Bucquet thought it proper to diſtinguiſh quartz from rock cryſtal, and to make a particular genus of each. He has alſo obſerved, that this ſtone quenched in water, after having been heated red for ſeveral ſucceſſive times, communicated acid properties to the fluid. Future experiments muſt determine whether this diſtinction be well founded. F.

3. Opake, or milky quartz.
4. Fat quartz.
5. Weathered or rotten quartz.
6. Green, blue, or violet quartz; priſm of amethyſt.
7. Yellow quartz of a lamellated fracture.

Topaz { Saxon.
Braſilian.

Theſe topazes have all the characters of quartz.

Genus II. FLINT, AGATE.

Flints and agates form ſmall round maſſes, moſt commonly opake) though ſometimes ſemi-tranſparent) either hollow or ſolid, variouſly coloured and diſpoſed in ſtrata; in chalk, as is the caſe with flints; or in clay, as are the agates. Their fracture is ſometimes ſcaly.

Species.

1. Grey flint.
2. Yellow flint.
3. Red flint.
4. Corneous flint; gun-flint.
5. Brown flint; Egyptian.
6. Tranſparent ſpotted flint; German agate.
7. Red agate; Cornelian.
8. Pale red agate.
9. Brown or yellow agate; ſardonyx.
10. Onyx; concentric laminæ.

11. Laminated agate, diſpoſed in horizontal layers. Much of the appearance of the laminæ, and their poſition relative to the figure of the ſtone, depends on the cutting.
12. Agate with figures.
    - Dendrites; herborized agates.*
    - Antropomorphites.
    - Zoómorphites.
    - Uranomorphites.
13. Agate apparently mouldy, or marked with ſmall greeniſh points, generally owing to moſſes.
14. Agate of four colours; elementary.
15. Grey agate; grey chalcedony.
16. White or milky agate chalcedony.
    - in beds.
    - in ſtalactites.
    - worn round; cacholong.
17. White agate, reflecting the light in a peculiar manner called chatoyant
    - Chatoyant agate of the lapidaries.
    - Cat's eye.
    - Oculus mundi, or hydrophane.
    - Opal.
    - Giraſol.
18. Brown agate, with brilliant gold coloured ſpecks. Avanturine.
19. Oriental agate.
20. Agate incloſing water.

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* M. Daubenton has ſhewn, in a memoir read to the Academy, that herborized ſtones contain very fine moſſes, or ſmall grains of black iron ore.

That the formation of quartz, agates, and flints, is owing to water, is evident from

1. Their form.
2. Their laminæ, or beds.
3. Their moſſes.
4. The water they contain.
5. The organic matters included in them, as in the moſſy or mouldy agates.

The hiſtory of the gæodes likewiſe prove this truth. Theſe are ſtony boxes filled with cryſtals; in which ſilex and quartz are found diſpoſed in concentric laminæ.

Genus III. Organic Matters converted into Silex, or Agate.

The organic form ſtill viſible, together with the characters of quartzoſe ſtones, diſtinguiſh them from the three other genera of this order.*

Species.

1. Petrified wood; ſtill fibrous, and ſuſceptible of poliſh.
2. Wood, whoſe ſpecies is diſtinguiſhable on account of its texture. Fir.
3. Sea urchins and madrepores, converted into ſilex.

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* It would, perhaps, be much more natural to form a particular claſs of animal and vegetable ſubſtances, altered during their ſtay in the earth. This claſs might be named foſſils, and might be placed at the end of the organized kingdom. Note of the author.

4. Shells agatified.
5. Carpolites; theſe have been falſly regarded as petrified fruits; they are ſmall ludus helmontii ſilicified.
6. Entrochites.
7. Lapis frumentarius ſiliceus.

It gives fire with the ſteel, does not efferveſce with acids, and ſeems to be formed by the aſſemblage of cornua ammonis, divided perpendicularly to their volutes.

There are two opinions concerning petrifaction. According to the one, the organized matters are entirely converted into ſtone. According to the other, the void ſpaces left in ſoft earths by animal ſubſtances, or the intervals in the texture of vegetable bodies, have been filled by the gradual depoſition of earthy matter. It has been obſerved, that vegetable matters almoſt always become quartzoſe, while animal matters moſt commonly become calcareous, and that vegetables ſcarcely ever paſs into the calcareous ſtate, at the ſame time preſerving their texture.* This obſervation may ſuffice to ſhew, that there is no ſuch thing as petrifaction properly ſo called, or real change of organized ſubſtances into ſtone. For, 1. Shells and madrepores ſuffer no other change than the loſs of their mucilage or animal gluten by putrefaction, and become thin calcareous ſkeletons, ſuch as they exiſted entire during the life of their inhabitants. 2. The pretended petrifactions of wood, are nothing more than depoſitions of vitrifiable earth. In proportion as the fibres are deſtroyed by putrefaction, quartzoſe earth is depoſited in the cavity, which retains the organic figure, and at length when no more vegetable matter is left, the petrifaction is completed.

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* Since the diſcovery of the ſparry gas, which has the property of depoſiting quartzoſe earth, ſome naturaliſts have thought that petrifaction is owing to a ſimilar phenomenon; but this opinion can be only regarded as an hypotheſis, till the exiſtence of an acid holding quartzoſe earth in ſolution in the bowels of the earth can be ſhewn. Note of the author.

Genus IV. JASPER.

Jaſper poſſeſſes all the characters of quartzoſe ſtones. It is not fuſible; but loſes its aggregation by heat. It is a very hard ſtone, ſuſceptible of a beautiful poliſh, opake, and variegated with different colours. Its fracture is vitreous and dull. It is very ſeldom ranged in ſtrata; but moſt commonly forms conſiderable maſſes or veins in rocks. It is alſo found in ſmall round maſſes. Moſt of the ſamples of jaſper are mixtures of quartz and chalcedony. Some contain calcareous ſpar.

The ſpecies of jaſper have been greatly

multiplied by naturaliſts. They may be reduced to the following:

Species.

1. White jaſper.
2. Grey.
3. Yellow.
4. Red.
5. Brown.
6. Green.
7. Veined.
8. Spotted.
9. Green, with red points. Blood ſtone.
10. Flowered.

Toys, and more eſpecially cups and ſaucers, are made of jaſper. Many antique ſculptures are in ſtones of this nature.

Genus V. Grit-ſtone, or Free-ſtone.

Grit-ſtone is opake, of a granulated fracture, much leſs hard than quartz or flint. It exiſts in enormous maſſes, more or leſs hard, and of a grain coarſer or finer in different ſpecimens.

Species.

1. Grit-ſtone cryſtallized in rhomboids. M. de Laſſone has proved that their figure is a conſequence of their containing calcareous earth.*

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* Memoirs of the Academy of Sciences for the year 1777.

2. Grit-ſtone in the form of cauliflowers, balls, &c.
3. Grit-ſtone in ſtalagmites.
4. White.
5. Grey.
6. Red.
7. Black, or brown.
8. Veined.
9. Figured, or dendritical.
10. ———, whoſe aggregation is deſtroyed; ſand.

The following are the varieties of ſand:

Varieties.

1. Quick-ſand.
2. Angular ſand.
3. Sand rounded by the action of water.
4. Pure white ſand.
5. Micaceous ſand; glarea.
6. Yellowiſh ſand mixed with clay; founder's ſand.
7. Ferruginous ſand; yellow.
8. Ferruginous ſand; black.
9. Blue ſand; from copper.
10. Violet ſand; from tin.
11. Auriferous ſand.

Order III. Argillaceous Earths and Stones.

They have a greaſy feel; are kneadable; ſtick to the tongue when dry; are foliated; often coloured; are diſpoſed in beds or ſtrata, and in large maſſes.

Their aggregation is leſs ſtrong than that of quartzoſe ſtones. They have a greater tendency to combination, and are therefore moſtly altered. Heat cauſes them to contract in their dimenſions, and gives them ſo great a degree of hardneſs, that they emulate the quartzoſe ſtones, and like them give fire with the ſteel. Water reduces them into paſte, and in larger quantities divides them, and renders them pure by the mechanical ſubſidence of the groſſer ſubſtances they may contain. They retain water ſo ſtrongly, that they cannot be again totally deprived of it.

Part of their ſubſtance combines with acids. Some chemiſts have ſuppoſed that clay is nothing but the ſiliceous earth changed by the vitriolic acid; but this opinion is not founded on any direct proofs.

Many naturaliſts have thought that vitrifiable earths, by long expoſure to external agents, water, air, and heat, become more and more divided, and are at laſt reduced to ſuch a degree of ſubtlety, as to be ſoft to the touch, and ſuſceptible of union with water; or in a word, that they become clay. This theory being founded on ſome accurate obſervations, ſeems to deſerve more confidence than the former; but neither the one nor the other are completely proved.

On the two properties of clay, namely, its ductility when ſoftened by water, and the hardneſs it acquires by baking, are founded the arts of making tiles, bricks, and all the varieties of pottery; the details of which belong to the hiſtory of theſe earths.

Naturaliſts have deſcribed a great number of ſpecies of argillaceous earths; and have confounded with them many which are not argillaceous, as well as certain compound ſtones, as ſerpentine, zeolite, trapp, &c.

The name of argill, or clay, ought not to be given to any earths but ſuch as harden in the fire, are kneadable with water, and form alum with the vitriolic acid.

M. Macquer, who has examined a great number of clays,* found none abſolutely pure. The colour and fuſibility of many of the ſpecimens, are owing to the admixture of different combuſtible and metallic ſubſtances.

The late M. Bucquet diſtinguiſhed them into four genera.

Genus I. SOFT AND DUCTILE CLAYS.

They may be kneaded when firſt dug out of the earth; they become dry in the air.

Species.

1. White clay; pipe clay.
2. Sandy clay.

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* Academie des Sciences, 1758.

3. Ductile blackiſh clay; for white pottery.
4. Clay with mica, kaolin; partly fuſible; for porcelain.
5. Metallic clay; fuſible; ſealed earth, Armenian bole.
6. Pyritous clay; fuſible; blue, green, or marbled; for common pottery.

Genus II. DRY FRIABLE CLAYS, TRIPOLIS.

All the clays which M. Bucquet ranked among the tripolis, are found dry in the earth. They are all formed in beds or ſtrata, frequently very thin. They all wear away by rubbing with the finger, and are reduced into powder. They imbibe water with great avidity, and ſtick to the tongue.

1. Dry, grey, foliated clay; fuller's earth.
2. Red tripoli. Some ſuppoſe it to be a volcanic production.
3. Grey tripoli.
4. Black tripoli.
5. Rotten ſtone; of an olive grey.

Genus III. Shiſti.

The ſhiſti are laminated ſtones, which eaſily ſplit into plates; they are very much compounded and fuſible. They form large blocks, placed with various degrees of obliquity in the interior parts of the globe. Almoſt all the quarries of this ſubſtance have impreſſions on their upper ſurfaces, of parts of plants, of the claſſes of ruſhes, fern, &c. and of ſhells, fiſhes, inſects, &c.

Species.

1. Black ſhiſtus, friable; ampelite.
2. Fiſſile ſhiſtus, ſlate.
3. Black ſhiſtus, hard, ſlate for writing.
4. Red, brown, &c. ſhiſtus.
5. Shiſtus, with vegetable and animal impreſſions.
6. Very hard ſhiſtus, for ſharpening razors.

Genus IV. FELDT-SPAR.

It is formed by rhomboidal laminæ; its fracture is ſpathoſe; it gives fire with the ſteel; whence it has been called ſpatum ſcintillaris. It is harder than the ſhiſti, and is fuſible. Mr. Bucquet thought it to be an argillaceous ſtone, coloured by iron. M. Monnet ſays it is compoſed of quartz, clay, magneſia, and a ſmall portion of calcareous earth. The difference of opinions reſpecting the nature of feldt-ſpar, ariſes from its not being yet well known. Future experiments may ſerve to fix its place.*

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* Father Pini, an Italian naturaliſt, is the firſt who diſcovered the feldt-ſpar in a cryſtallized form. Since his time it

Species.

1. Priſmatic feldt-ſpar.*
2. White feldt-ſpar.
3. Red feldt-ſpar.
4. Green feldt-ſpar.
5. Blue feldt-ſpar.

Order IV. Falſe Clays.

They reſemble clays only in their foliated texture, and greaſy appearance; ſome harden in the fire.

They differ from clays, in not making a paſte with water; and moſt part of them melt in the fire. With the vitriolic acid they afford a ſalt in needles, which does not change in the air, is ſoluble in four or five times its weight of water, and does not ſwell in the fire. In a word, it is not alum. Theſe characters have been given by M. Bucquet,

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it has been found in many parts of France, particularly at Roanne in Forez, where they are very regular. I have given a full deſcription of the feldt-ſpar found in the granites of Alençon, which is one of the moſt regular and beautiful I know. See my Memoires de Chimie. Note of the author.

* M. Daubenton has placed it among the ſcintillating ſtones. Three characters diſtinguiſh it from every other kind of ſtone. Its texture is ſpathoſe, it is chatoyant, and it gives fire with the ſteel. From theſe characters, this genus ought to contain more ſpecies than the late M. Bucquet attributed to it. M. Daubenton reckons the fiſhes eye, the avanturine, the Labrador ſtone, &c. of this genus. See his tables. Note of the author.

Bucquet, who examined many of theſe ſtones. But as they are yet very little known, they may be placed after the clays.

Genus I. LAPIDES OLLARES, HARD.

Their texture is ſcarcely at all foliated; their appearance is greaſy; they take but a bad poliſh.

Species.

1. Grey lapis ollaris from Sweden.
2. Greeniſh colubrine of Sweden.
3. Yellowiſh ſoap-ſtone of China.
4. Brilliant green; jade. The lapis nephriticus, and thoſe of Otaheite, were varieties of jade according to M. Bucquet. We may obſerve that jade is very hard, and gives fire with the ſteel. It is doubtleſs after Pott, that M. Bucquet placed it among the lapides ollares.
5. Dirty green lapis ollares. Colubrine.
6. Serpentine. A ſtone of deep green, or blackiſh colour, with black ſpots or veins, like the ſkin of ſerpents. We have placed it at the end of the lapides ollares, on account of its aſpect, though it ſeems to be a compound ſtone.

Genus II. TENDER LAPIDES OLLARES, STEATITES or SMECTITES.

They have a more ſoapy feel than the preceding. They are very eaſily cut; they lather with water; ſome kinds have a ſtriking reſemblance with ſoap.

Species.

1. White ſteatites, compact; Briançon chalk.
2. Brilliant or glittering Briançon chalk. Venetian talc of the druggiſts.
3. White ſteatites from Norway.
4. Red marbled ſteatites from Norway.
5. Reddiſh ſteatites from Norway.
6. Green compact ſteatites from Norway.
7. Green and red ſteatites from Norway.
8. Green ſteatites, foliated; tender colubrine from Norway.
9. Black ſteatites.
10. Grey and brilliant ſteatites, plumbago, molybdena, and improperly black lead. This being pulverized, and made into a paſte with iſinglaſs, is incloſed in ſmall wooden cylinders, which are cut to a point at

at the end, and uſed as crayons or pencils.*

Genus III. TALC.

It is compoſed of poliſhed and glittering laminæ, of a jelly-like tranſparency, applied one on the other. It appears that theſe laminæ are ſometimes cryſtallized in hexagons, or ſections of ſix-ſided priſms. By a violent fire it melts into a coloured glaſs.

Species.

1. Talc in large tranſparent plates; Muſcovy glaſs.

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* Since the death of M. Bucquet, and the firſt impreſſion of this book, Meſſrs. Scheele, Grahn, and Hielm have made very ſucceſsful reſearches into the nature of plumbago. They have diſcovered that this ſubſtance is a kind of ſulphur formed, according to them, by the combination of the aerial or cretaceous acid with phlogiſton. We ſhall give its hiſtory after that of ſulphur. The ſame chemiſts, and eſpecially M. Scheele, have made a proper diſtinction between molybdena and plumbago, which naturaliſts have, till lately, confounded together. Molybdena is regarded by Scheele as a compound of ſulphur and a peculiar acid, which he called the acid of molybdena. (See the hiſtory of ſulphur.) It is the plumbago which is uſed for crayons. Note of the author.

The Engliſh pencils are made by fixing or ſetting one or more ſlips or pieces of plumbago in a groove between two ſlips of cedar, which are then glued together. The inferior ſort ſold in the ſtreets by Jews are the kind mentioned by the author. T.

2. Talc in very ſmall ſilvery-white ſpangles.
3. Talc in very ſmall gold coloured ſpangles.

The two laſt mentioned are uſed as writing ſand under the name of ſilver or gold duſt.

4. Talc worn into the form of pebbles.
5. Talc in black ſpangles.
6. Talc in mixed brilliant ſpangles.

Genus IV. AMIANTHUS, ASBESTOS.

This genus of ſtones is formed of fibres or threads placed parallel to each other, or interlaced together like tiſſue; the fibres are either rigid or flexible, and differ from each other in thickneſs, length, and colour. The ancients wove them into a cloth, which was called incombuſtible linen, and uſed to envelope their dead when burned on the funeral pile. It ſerved to retain and collect their aſhes, &c.

By a violent fire amianthus is eaſily melted into a coloured opake glaſs.

Species.

1. Aſbeſtos, hard and grey, with parallel fibres; ligneous aſbeſtos.
2. ———, hard and green in parallel fibres.

3. Aſbeſtos, hard and green, with fibres in bundles.
4. ———, with diverging fibres.
5. ———, with ſoft fibres.
6. Amianthus, hard, with parallel greeniſh fibres.
7. ———, hard, with parallel white fibres.
8. ———, with white brilliant fibres in bundles.
9. ———, in hard bundles, yellowiſh.
10. ———, white and flexible.
11. ———, grey.
12. Mountain fleſh.
13. Mountain leather.
14. Mountain cork.

SECTION II.

Compound Earths and Stones.

They are not diſtinguiſhable by the eye from thoſe of the preceding ſection. As to their characters, they are formed of matter apparently homogeneous, almoſt always coloured, moſtly opake, but ſometimes tranſparent, and moſt ſpecimens are regularly cryſtallized. Their form and colour ſerve to diſtinguiſh the genera. They are all very fuſible, and afford different kinds of glaſſes. Their fracture is ſometimes vitreous, ſometimes ſcaly. In theſe ſubſtances it is, that nature has combined earths, ſalts, and metals together.

M. Bucquet divided theſe ſtones into two orders. In the firſt were comprehended earths and ſtones, compoſed by water, to which he gave the characters proper to the products of that element. He divided this order into two genera; namely ochres, and zeolite. In the ſecond, he placed ſchorl, macles, trap, azure ſtone, the fuſible precious ſtones, volcanic cryſtals and glaſſes, and pumice ſtones. He regarded theſe eight kinds of ſtones as the products of fire. We have conſidered it as our duty to exhibit the ideas of this celebrated chemiſt; but as the diſtinctive characters of theſe two orders are not yet eſtabliſhed on numerous and concluſive proofs, and as M. Bucquet himſelf propoſed them as mere ſketches, we ſhall here give the hiſtory of the ſeveral kinds in ſucceſſion, without adhering to his method of diviſion.

Genus I. OCHRES.

Ochres are leſs acted on by water than clays. They are friable, and ſoil the fingers; their colour is cauſed by metallic ſubſtances, almoſt always iron. When urged by fire, their colour becomes more intenſe. A violent heat melts them. They are uſed as pigments.

Species.

1. Yellow ochre.
2. Red ochre, blood colour.
3. Green ochre; earth of Verona.
4. Brown ochre; Umber.

Genus II. Zeolite.

Zeolite, firſt deſcribed by Cronſtedt, is a ſtone compoſed of needles diverging from a centre. It neither gives fire with ſteel, nor effervefces with acids. Expoſed to the action of fire it ſwells up, and affords a white glaſs reſembling enamel. By diſtillation it affords much water. The reſidue contains, according to Bergman, ſiliceous, argillaceous, and calcareous earths. M. Bucquet, who likewiſe made the analyſis of this ſubſtance, affirms, that he found very little ſiliceous earth, and a peculiar earth, which is neither argillaceous nor calcareous, but forms with the vitriolic acid a cryſtallizable ſalt in ſmall ſhining plates, reſembling ſedative ſalt, which he has thought proper to call zeolitic earth. Theſe two earths are cryſtallizable together by the aſſiſtance of water, which makes more than one eighth of the whole compoſition. M. Bucquet obtained one drachm and a half of water from an ounce of the white zeolite, of the iſland of Ferro.* The property of forming a jelly with the different acids is not peculiar to this ſubſtance, but is common to the azure ſtone, tin, and to ſeveral ores of iron, &c. Its origin and formation are unknown; but it is abundantly found among the products of volcanos. It is very plentiful in the iſland of Ferro. We are acquainted with ſix ſorts.

Species.

1. White zeolite in tranſparent faſces.
2. White zeolite in compact faſces.
3. Red zeolite.
4. Green zeolite.
5. Blue zeolite.

The red, green, and blue have not been examined.†

Genus III. Schorl.

Schorl is a ſtone of a dark colour, violet, black, or green, rarely white, moderately brittle, and giving fire with ſteel. It readily melts into a black opake glaſs. According to M. Bucquet, it contained clay and iron in combination. Bubbles have been obſerved in the internal part of ſchorls, ſimilar to thoſe in the ſlags at glaſs-houſes.

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* Mémoires des Savans étrangers; tom ix. page 576.

† M. Pelletier, the pupil of M. D'Arcet, has given (Journal de Phyſique, 1782, p. 420.) a memoir on the analyſis of the zeolite of Ferro. By very accurate experiments he found that 100 grains of this ſtone contain 20 of pure clay, 8 of lime, 50 of ſiliceous earth, and 22 of water. Note of the author.

Its origin is not well known. Some perſons regard it as a volcanic product, becauſe it is frequently met with in places which have been burned; but it is likewiſe found among matters formed by water.

Species.

1. Violet, cryſtallized ſchorl.
2. Violet, in fibrous maſſes.
3. Black, in priſms of four, ſix, eight, or nine ſides; with pyramids of two, three, or four faces, like the violet ſchorl.
4. Black ſchorl in maſſes.
5. Green ſchorl in lamellated maſſes.
6. White bluiſh ſchorl.
7. Electric ſchorl of a reddiſh yellow, tourmaline.

Genus IV. MACLES.

By this name we underſtand certain priſmatic opake ſtones, of a dirty appearance, often regularly formed. Their analyſis made by M. Bucquet, ſhews that they approach the nature of ſchorls. They are compoſed of iron and clay.

Species.

1. Tetrahedral macle, whoſe ſection ſhews the figure of a croſs. It is found in a kind of hard, deep

blue ſhiſtus of Britany; it is very adheſive; and very brittle. When broken, two blueiſh lines are ſeen on its tranſverſe ſection, interſecting each other in the middle, and forming a croſs. Sometimes the middle of the priſm appears to be filled with a matter ſimilar to that of the gangue.

2. Croſs-ſtones. Hexahedral priſms, articulated and croſſed in the middle like the arms of a croſs. They are found in the leaves of yellow mica. The two branches ſcarcely ever croſs each other at right angles.

Genus V. Trap.

Trap is a hard ſtone of a fine grain, of a foliated fracture, with angular indentations like ſteps. It is of a deep blackiſh green, often inclining to the colour of ochre: ſufficiently hard to give fire with ſteel, and affords a blackiſh glaſs in the fire. It is always covered with a kind of matter leſs hard than its own ſubſtance. Its component parts, according to M. Bucquet, are clay and iron, the latter being in the proportion of twenty-five pounds per quintal; ſo that it may be ranked among iron ores. M. Daubenton conſiders it as a ſhiſtus containing quartz in ſand. We know but of one kind of trap, which is that above deſcribed.

Genus VI. AZURE STONE; LAPIS LAZULI.

Its colour, the fineneſs of its grain, the analyſis, which ſhews that this ſtone contains iron, are reaſons for placing this immediately after the foregoing. There are three ſpecies.

Species.

1. Oriental azure ſtone.
2. Azure ſtone of a pale blue, frequently inclining to purple.
3. Armenian ſtone; ſpotted with white and pale blue.

The beautiful blue called ultramarine, which is uſed by painters, and is one of the moſt unchangeable we are acquainted with, is prepared from this ſtone.

Genus VII. FUSIBLE CRYSTALS CALLED GEMS.

The chemical differences obſerved between the ſeveral kinds of precious ſtones or gems, induced M. Bucquet to ſeparate them from each other, and to claſs each in the order or ſection to which it ſeemed to belong. Thoſe which are ranked in this place are evidently of a compound nature. M. Bergman found them to contain many ſubſtances, ſuch as ſiliceous earth, clay, lime and iron. They are all fuſible, and of a laminated ſtructure. Their fracture is lamellated.

Species.

1. Aqua-marine.
2. Emeralds.
3. Chryſolite.
4. Ruby.
5. Bohemian garnet.
6. Garnet.

Genus VIII. Volcanic Cryſtals.

In this genus M. Bucquet comprehended all regular formed ſtones, tranſparent and coloured like the gems, but which have neither their hardneſs nor brilliancy. They are found in cavities lined with ſmall brilliant particles of the ſame nature agglutinated together. They are met with in the neighbourhood of volcanos, but it is not known whether they are formed by fire. We admit three ſpecies.

Species.

1. Volcanic chryſolite; polyhedral cryſtals of a golden green.
2. Volcanic hyacinth; polyhedral cryſtals of orange yellow.
3. Volcanic garnets. They greatly reſemble ſingle garnets, but they are irregular and ſcattered among, or on the ſurface of, brilliant lavas,

vas, together with the two foregoing.

Genus IX. Pumice Stones.

Moſt of the pumice ſtones appear to conſiſt of an aſſemblage of vitreous fibres, like threads wound on a clue. Their ſubſtance is a true combination of various matters fuſed by volcanic fires.

Pumice ſtones may be diſtinguiſhed into four kinds, each of which has many varieties.

Species.

1. White fibrous pumice ſtone.
2. Coloured fibrous pumice ſtone.
3. Cellular and light pumice ſtones.
4. Cellular and compact pumice ſtone.

Genus X. VOLCANIC GLASS.

The glaſſes melted and ejected by volcanos are formed of earthy and ſaline matters, coloured by iron, or other metallic matters. They are true chemical combinations performed by nature in the dry way.

Species.

1. Cellular greeniſh glaſs.
2. Blackiſh glaſs; cellular, or in agglutinated fibres.
3. Beautiful black tranſparent glaſs, Iceland agate, lapis obſidianus of the ancients.

SECTION III.

Mixed Earths and Stones.

It is very caſy to obſerve the leading character of the ſtones of this ſection, as mere inſpection is ſufficient to ſhew the different matters which compoſe them; eſpecially if they be properly compared with the varieties of the preceding ſections. We have already remarked, that mechanical ſeparation of their ſeveral parts is firſt required before the chemical analyſis can be undertaken. If theſe mixed ſtones be expoſed intire to the action of fire, they melt with more or leſs facility into glaſſes of different colours and appearance, according to the nature of the parts which compoſed the mixture.

They appear to have been formed by the junction of the different ſubſtances we ſee; and this junction muſt have been made either by means of water or fire. This laſt conſideration engaged M. Bucquet to divide this ſection into two orders like the foregoing. The firſt order comprehends the mixed ſtones formed by water; and the ſecond, ſuch as have been compoſed by fire. This diviſion being founded on a much greater number of facts than the preceding, induces us to admit it with much more confidence,

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Order I. Earths and Stones of a mixed Nature, formed by Water.

Genus I. Petro-ſilex.

By this name naturaliſts denote a ſtone of an intermediate hardneſs between the ſofter ſtones, and thoſe of the ſiliceous order. M. Daubenton has placed it among the vitreous ſtones, becauſe it gives ſparks with the ſteel, and its fracture is vitreous, though rather ſcaly. Petro-ſilex has a ſemi-tranſparency reſembling wax. It is dull, and not at all ſhining, but rather of the aſpect or defective kind of poliſh which tallow uſually has. Its grain is fine, and very cloſe. It is found in very large maſſes, and often in beds or ſtrata of different ſhades, lying above each other. M. Bucquet gives us its chemical character; that of melting by fire into an opake glaſs. Its mixture is very far from being as evident to inſpection, as that of the following genera. It ſeems to have the ſame characters as the compound ſtones,* and is, for that reaſon, placed at the head of this third ſection. It ſerves, as it were, as a connecting link between the two.

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* It is neceſſary to obſerve that theſe characters, founded on the action of fire on ſtones, are eſtabliſhed by experiments made by the Duc de la Rochefoucauld, and by M. Bucquet, in an excellent melting furnace conſtructed for that purpoſe in the laboratory which the diſtinguiſhed encourager of the ſciences here mentioned has devoted to every kind of reſearch that may tend to the advancement of

The form of its beds, that matters it frequently contains, and eſpecially the maſſes of it, which are placed in the bowels of the earth, ſhew that it is formed by means of water.

Species.

1. Grey petro-ſilex.
2. Reddiſh.
3. Greeniſh.
4. Brown.
5. Black.
6. Spotted.
7. Veined.

Genus II. PUDDING STONE.

Pudding ſtone is a mixture of flints connected by a cement of a different nature. This cement is either of the nature of freeſtone, or argillaceous, or ochreous. It is ſometimes hard, and reſembles ſilex.

It is not at all doubtful, but its formation is effected by water. It is always found on the ſea coaſts, or in places which have been covered by water, and afterwards deſerted by that element.

of chemiſtry. I have examined moſt of thoſe reſults, which will doubtleſs be communicated to the learned world. This communication will confirm the valuable ſeries of experiments made by M. D'Arcet, with the addition of many facts ſerving to eſtabliſh the chemical characters propoſed by M. Bucquet, to be uſed in the claſſing of ſtones. Note of the author.

Species.

1. Sandy pudding-ſtone.
2. Ochreous.
3. Argillaceous.
4. Siliceous.
5. Agatified; ſuſceptible of the fineſt poliſh.

Genus III. GRANITE.

Granite is formed of three ſtony matters in fragments of greater or leſs magnitude united together. Theſe three ſubſtances are quartz, feldt-ſpar, and mica.

It gives fire with ſteel on account of the quartz and feldt-ſpar it contains; its fracture is irregular, and very coarſe grained; it is fuſible, but in different degrees, according to the reſpective quantities of the matters which compoſe it. It takes a poliſh more or leſs bright, according to the fineneſs of its grain, and the hardneſs of the principles which enter into its compoſition. Some ſpecimens change by expoſure to the air. This laſt phenomenon has ſerved to diſtinguiſh the ancient from the modern granites. The ſpecies of granite have been greatly multiplied.* They may, however, be reduced to the following:

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* Modern philoſophers have paid great attention to the natural hiſtory of granite. M. de Sauſſure has given much new and important information on this ſubject in his *Voyage des Alpes*. All granites are not formed by the mixture of the three ſtones mentioned in the text. There are ſome which contain

Species.

1. White granite.
2. Grey.
3. Red.
4. Brown.
5. Green.
6. Black.
7. Dull and friable; altered by expoſure to air.

Genus IV. PORPHYRY.

Porphyry is a ſtone covered with ſpots in a ground of a red or other colour. It gives many ſparks with the ſteel.

It differs from granite by its greater hardneſs, and its being ſuſceptible of a much more lively poliſh. It appears to be formed of feldtſpar and ſchorl united by a quartzoſe cement.

The cement or paſte, which forms the baſis of porphyry, is of a very fine and cloſe grain. The different fragments, which are bedded in this ground, are in general much ſmaller than thoſe of granite. This ſtone is fuſible, and affords a coloured glaſs. All the ſpecies of porphyry may be reduced to the ſeven following:

Species.

1. Red porphyry, with large ſpots.
2. ————————, with ſmall ſpots.

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tain ſchorl inſtead of mica; others contain both ſchorl and mica. The mixture of quartz and feldt-ſpar only is called granitin; and the ſtone compoſed of quartz and ſchorl is called granitello. See De Sauſſure's *Voyages dans les Alpes*. Note of the author.

3. Green porphyry, with large ſpots.
4. ————————, with ſmall ſpots.
5. Black porphyry, with large ſpots.
6. ————————, with ſmall ſpots.
7. Coarſe porphyry of a dirty red, approaching to the nature of ſandſtone.

Genus V. OPHITES OR SERPENTINE.

Pliny gives the name of ophites to ſtones ſpotted like the ſkins of ſerpents. M. Bucquet conſidered them as ſpecies of porphyry; but harder, more ancient, and of a mixture much more intimately combined. The name of ſerpentine, or hard ſerpentine, has been given to them. On comparing this ſtone with porphyry, it is ſeen that ſerpentine, as well as porphyry, is compoſed of a quartzoſe paſte, together with feldt-ſpar and ſchorl, but that the feldt-ſpar in the former is in large rhomboidal fragments, while it is very ſmall in the porphyry.

Serpentine gives ſparks with ſteel. Its fracture is fine, and rather ſcaly. It melts in the fire.

The following are the principal ſpecies of ſerpentine we have ſeen.

Species.

1. Ophites of a deep green colour, with large white ſpots.
2. Ophites of a deep green colour, with oblong pale green ſpots.

3. Ophites ſimilar to the foregoing, but with very ſmall, and ſcarcely perceptible ſpots. Many ſavage nations cut them into coins. They have been called thunder-ſtones.
4. Ophites of a brown colour, with irregular oblong ſpots of a roſe coloured white.

The origin of ophites is very obſcure. It is not well known whether they are the product of water, or of fire. As they have ſome analogy with porphyry, we have placed them after that ſtone.

Order II. Earths and Stones of a mixed Nature formed by Fire.

CONTINUATION OF THE VOLCANIC PRODUCTS.

There is no diſpute concerning the origin of ſubſtances which compoſe this order, ſince they are never found but in the neighbourhood of volcanos, or in places where volcanos have formerly exiſted: beſides which, they exhibit all the characters of products of fire. By joining the genera of this order with thoſe deſcribed among the compound ſtones, a complete ſeries of volcanic products will be had.

We ſhall not comprehend under the name of volcanic products all the ſtones or earths found in the neighbourhood of volcanos, which are not at all altered by fire; as is the caſe with the greater part of the ſtones we have already deſcribed, eſpecially granite, clays, &c. as well as many ſaline ſubſtances, together with calcined, melted, ſublimed, or vitrified matters. It would be an uſeleſs repetition to take notice of their hiſtory in this place. We ſhall elſewhere take notice of their exiſtence in the neighbourhood of volcanos, and the changes produced in them by the ſubterraneous fires.

Genus I. VOLCANIC ASHES.

The name of volcanic aſhes has been improperly given to certain pulverulent earthy matters found near volcanos. They appear to owe their origin either to the ſubſtances mixed and thrown out by volcanos, or to lavas altered by the contact of air and water. M. Bucquet conſidered them as combinations of clay and iron. They frequently obey the magnet. We are acquainted with two ſpecies.

Species.

1. Rapillo; a pulverulent matter of a blackiſh grey, found near the craters of volcanos.

Rapillo contains garnets and ſchorls, whoſe form is diſtinguiſhable, though their angles have been ſoftened and encruſted apparently by ſome matter in fuſion.

2. Puzzolana. This ſubſtance is named from the town of Puzzoli, where it was very anciently made uſe of. It is an argillaceous earth, charged with iron, and of different colours, according to the ſtate of the metal. It is found of a grey, yellow, red, brown, or black colour. By fire it melts into a black enamel. The great utility of this ſubſtance conſiſts in its forming a kind of mortar, which has the property of becoming hard in water. M. Faujas de St. Fond has found it in Vivarais. He thinks that theſe earths are formed by the alteration and deſtruction of the porous lavas, and even of the baſaltes. This philoſopher, in his reſearches concerning puzzolana, has given a detail of the proceſſes for conſtructing edifices both in the air and under water with this ſubſtance.

Genus II. LAVAS.

This name is given to the melted and ſemi-vitrified matter of volcanos. They moſt commonly flow down the ſides of mountains, whoſe internal parts are on fire, and form rivers of burning matter, which ſometimes flow to prodigious diſtances, to the deſtruction of every thing in their way. Their heat and maſs are ſo conſiderable, that they are ſeveral years in cooling. During this period, they crack and ſeparate into maſſes, which are ſometimes regularly formed. Such appears to have been the origin of baſaltes. A great variety of theſe ſtones are found in cabinets of natural hiſtory. They are in general compoſed of a paſte of a grey colour, more or leſs deep, with great varieties of texture and hardneſs, in which are bedded cryſtals, or irregular fragments of ſchorl, garnet, glaſs, zeolite, &c. conſtituting a true mixture. It is impoſſible to give any general character of lavas, as they all differ in their grain, conſiſtence, hardneſs, colour, mixture, &c. In general they are very fuſible, and afford a kind of black enamel, ſimilar to the glaſs of volcanos. M. Cadet has found them to contain clay, iron, copper, and quartz. Bergman thinks them to be compoſed of ſiliceous, argillaceous, and calcareous earths, with iron. Many, and more eſpecially the compact lavas, have the property of acting on the magnetic needle.

Species.

1. Soft lava of various colours, with cryſtals of black ſchorl.
2. Soft lava of various colours, with cryſtals of green ſchorl.

3. Soft lava of various colours, with cryſtals of white ſchorl.
4. Reddiſh lava, with blackiſh cryſtals.
5. Yellowiſh and ſaline lava.
6. Soft lava with cryſtals of garnet.
7. Chatoyant and porous lava.
8. Porous, grey lava.
9. Soft lava, blackiſh, with white cryſtals.
10. Grey lava, rather compact, interſperſed with opake, dodecahedral cryſtals, or garnets altered by fire.
11. Ancient lava, very compact, of a blackiſh grey, with ſpots of a deeper colour.

Genus III. BASALTES.

The deſcriptions given by naturaliſts of baſaltes, are very far from being exact. Many confound ſchorls and grenates with the true baſaltes, and no writer has given a good definition of the word. Some regard this ſubſtance as a volcanic product; others have ſuppoſed them to be formed by water. We think it proper, in conſequence of the valuable obſervations of Meſſrs. Deſmarets and Faujas de Saint Fond, to adopt the former opinion.

We may aſſume the following as the diſtinctive characters of baſaltes. A regular form; hardneſs ſufficient to give fire with the ſteel; cinereous grey colour inclining to black, and a manifeſt mixture of ſchorl or ſmall vitrified fragments, uſually of a deeper colour than the ground. The baſaltes are fuſible.

Some ſtones of this kind are of enormous magnitude, and exiſt in very conſiderable maſſes, whoſe formation ſeems to have been effected in times of the remoteſt antiquity. Such are, 1. The giants cauſeway, in the county of Antrim, in Ireland. 2. The rock of Pereneire, near Saint-Sandoux, in Auvergne, well deſcribed by M. Deſmarets. There are others regularly cryſtallized in ſmall priſms of three, four, or five ſides, &c. Their figure, magnitude, and diſpoſition is exceedingly various.

In general, theſe ſtones are ranged ſymmetrically, one beſide another. Their analyſis does not appear to have been yet made with ſufficient accuracy to authorize any decided account of their nature. They ſeem to be nothing elſe but lavas, apparently cryſtallized in conſequence of the cracks formed in them in every direction during their cooling. The ſingular varieties they offer, and their arrangement, ſeem to give much force to this opinion. Water ſeems to have inſinuated itſelf into theſe clifts, and to have there depoſited various earths, at the ſame time that it has produced ſome alteration on the correſpondent ſurfaces of the baſaltes. This is apparently the cauſe of the yellow or brown cruſts which ſeem to envelope them.

Species.

1. Baſaltes in very long polygonal priſms, without regular pyramids.
2. Baſaltes in ſhort priſms, truncated with three, four, five, or ſeven faces.
3. Baſaltes in ſhort polygonal priſms, terminated by a concavity above, and a convexity below. Articulated baſaltes.
4. Small quadrangular, triangular, &c. Baſaltes; formed by the fractures of the larger, and grouped with them.

Genus IV. SCORIÆ OF LAVAS.

The melted matter which conſtitutes lavas, is a mixture of many heterogeneous ſubſtances, differing in denſity and weight. During its cooling theſe ſeparate in the order of their ſpecific gravities. The ſcoriæ of lavas are bodies frequently of a ſpongy nature, which not having ſuffered as complete a fuſion as the lava itſelf, riſe above it by their comparative levity. In other reſpects they ſeem to be of the ſame nature, except that their principles are leſs perfectly mixed together. Cryſtals of ſchorl and granite are found in them as well as in the lavas themſelves.

Species.

1. Heavy volcanic ſcoriæ of a compact texture.
2. Black and cellular volcanic ſcoriæ.
3. Black and ſpongy volcanic ſcoriæ.
4. Black volcanic ſcoriæ, with twiſted fibres.
5. Yellow and ochraceous volcanic ſcoriæ.
6. Reddiſh volcanic ſcoriæ.

The two laſt have been manifeſtly altered by the contact of air, water, and acid vapors.

Such was the method in which the late M. Bucquet thought proper to claſs earths and ſtones in 1777 and 1778. Mineralogical chemiſtry has been greatly improved ſince that time. The analyſis of ſtones has been made in almoſt every chemical laboratory. Meſſrs. Bayen, D'Arcet, Monnet, De Morveau, Sage, Mongez, Pelletier, in France; Scheele and Bergman, in Sweden; Achard, Bindheim, and Hupſch, at Berlin; Woulfe, Withering, and Kirwan, in England, have examined a great number of ſtones and earths, and in conſequence of theſe numerous analyſes, the claſſification of theſe ſubſtances has ſuffered great changes; and two of the above-mentioned chemiſts have thought proper to publiſh ſyſtems of mineralogy,

ralogy, founded on the principles of bodies. But they have purſued a very different courſe from that of M. Bucquet, whoſe aim was to aſſociate the external characters with the chemical properties. Meſſrs. Bergman and Kirwan have paid ſcarcely any regard to the phyſical qualities in the claſſification of earths and ſtones. The nature, quantity, and proportion of their conſtituent parts have determined them in their methodical diſtribution. Their ſyſtem, though very uſeful in the promotion of chemical knowledge, cannot anſwer the purpoſe of diſtinguiſhing ſtones by their aſpect and ſenſible characters. It therefore appeared neceſſary to prefix to thoſe ſyſtems a natural method, as we have here done, with the intention, that each ſhould illuſtrate the other to the advantage of ſuch as undertake the ſtudy of minerals.

§ 11. The Chemical Diſtribution of Earths and Stones, according to Bergman.*

After ſhewing that the external characters are not ſufficient to diſtinguiſh minerals from each other, though they may be of great aſſiſtance when judiciouſly choſen,

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* The author in a note obſerves, that he has made uſe of the French edition of Bergman's Sciagraphia Regni Mineralis, tranſlated by Mongez. The Engliſh reader may recur to a tranſlation of this excellent ſmall work, publiſhed in London by Dr. W. Withering.

Bergman eſtabliſhes his principal diviſions of claſſes and genera on the compoſition and internal characters of the bodies. The principle, which is either the moſt abundant or the moſt active, in any mineral, is made uſe of as a guide in its diſtribution. He divides all minerals or foſſils into four claſſes, namely, ſalts, earths, bitumens, and metals. We ſhall only take notice of the earths in this place.

Bergman admits of five earths, ſimple and different from each other; namely, ponderous earth, lime, magneſia, clay, and ſiliceous earth.*

He firſt examines each of theſe earths in a ſtate of purity, though they are never found ſo in nature. He remarks that theſe five earths combined together may afford twenty ſpecies, viz. ten combinations of two; ſix of three; three of four; and one of the whole five. But as he ranks among the earths ſuch of their combinations with acids as as are not ſoluble in one thouſand times their weight of boiling water, the number of ſpecies is greater on this account. Beſides which, two earthy compounds conſiſting of like principles, may differ greatly in the proportion of theſe principles, and therefore have very diſtinct and different properties belonging to their reſpective combinations. Such are the grounds of diſtinction of the ſpecies admitted by Bergman, and by his commentator M. l'Abbé Mongez, who has made large additions to the labours of the Swediſh chemiſt. Here follows the ſpecies of each primitive earth according to this method.

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* Among theſe five earths, three have evident ſaline properties; namely, the ponderous earth, lime, and magneſia; and for that reaſon we ſhall give their hiſtory in the ſecond part of our work. Bergman, whoſe intention was to divide ſtones according to their principles, was neceſſitated to rank them among the earths, becauſe they are often united with each other. Many ſubſtances which this illuſtrious chemiſt has reckoned among the earths, are ſalts in our method. The Author.

Ponderous Earth.

Species I. Pure ponderous earth; it does not exiſt in nature, and is obtained by the decompoſition of the ponderous ſpar, as we ſhall ſee hereafter.

Species II. Aerated ponderous earth, or the combination of the ponderous earth with the aerial acid.

Species III. Vitriolated ponderous earth; ponderous ſpar; or the combination of the vitriolic acid with ponderous earth. This ſubſtance is abundantly found in mines. The Bolonian ſtone is a variety of this.

Species IV. Vitriolated ponderous earth, penetrated with petroleum, mixed with ſilenite, alum and ſiliceous earth; hepatic ſtone of Cronſtedt. This ſubſtance is ſpathoſe and brilliant; yellow, brown, or black; its odour is very ſtrong, and it does not efferveſce with acids. A centenary of this natural compound contains, according to the analyſis of Bergman, 33 parts of ſiliceous earth, 29 of pure ponderous earth, and 5 of clay, beſides lime, water, and vitriolic acid.

Lime.

Species I. Pure lime, or quick lime. Bergman did not know of its exiſtence in nature.

Species II. Aerated lime. Chalk, or calcareous earth. The combination of lime with the aerial acid. It is rarely pure. It often contains the marine ſalt of magneſia, calcareous marine ſalt, clay, ſiliceous earth or iron. Within, or at the ſurface of the earth, it conſtitutes lac lunæ, ſtony icicles, calcareous ſtones, marbles, calcareous ſpars, concretions, or ſtalactites, &c.

Species III. Aerated lime impregnated with bitumen or petroleum; ſwine-ſtone.

It is found in France at Villers-Cotterets, at Plombieres, at Ingrande in Anjou, at Rattwyk in Dalecarlia, at Kineculle in Weſtrogothland, at Kraſnaſelo in Ingermania, in Portugal, in Sweden, &c. It emits a fetid ſmell, when it is rubbed or heated; ſometimes the odour reſembles that of the urine of cats; and for this reaſon it has been called *lapis felinus* by ſome author. With acids it effervesces; in the fire it decrepitates, and loſes its odour and colour. When diſtilled in large quantities, it affords, 1. A fetid liquor, which reddens ſyrop of violets, and effervesces with acids. 2. A black ſtrong ſmelling oil, reſembling that of pit coal. 3. Concrete volatile alkali. The reſidue contains a little marine ſalt. This ſubſtance owes its diſtinguiſhing properties to the bitumen it contains.

Species IV. Fluorated lime. Fluor mineral, or vitreous ſpar, combination of lime, with the ſparry or fluor acid mixed with clay, ſiliceous earth, or a ſmall quantity of marine acid.

Species V. Lime ſaturated with a peculiar acid, probably metallic.[*] Heavy ſtone, tungſten of the Swedes. This is the heavieſt of all ſtones. It is found in ſmall yellow or red grains, in the mines of Baſtnas, near Ritterhutte in Weſtmanland; and alſo of a ſpathoſe, brilliant, and whitiſh appearance at Marienburgh, and at Altenburg in Saxony. It is often compounded with the white tin ore. It reſiſts the fire, and only vitrifies at the ſurface. It is not ſoluble in boiling water. The vitriolic acid ſeizes the lime. The nitrous acid, being added to a ſolution of this ſtone in volatile alkali, precipitates a white powder, which is the peculiar acid diſcovered by Scheele.[‡] The tungſten may be diſtinguiſhed from every other ſtone, by pouring the nitrous or marine acid upon it in powder, which laſt becomes of a beautiful yellow on being ſlightly heated. (See the Journal de Phyſique, 1783, vol. 22.)

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[*] Since found to be ſo. See Scheele's Eſſays, and De Luyart's on wolfram, both tranſlated into Engliſh, and publiſhed in London. T.

[‡] De Luyart's have ſhewn that this is a triple ſalt, conſiſting of wolfram-calx, volatile alkali, and nitrous acid. It is ſoluble in water, and has acid properties. The pure calx, though not evidently ſoluble in water, reſembles acids in its affinities with alkali and lime, and its inſolubility in acids. T.

Species VI. Aerated lime contaminated† with a ſmall quantity of muriatic magneſia, or marine ſalt of magneſia.

Species VII. Aerated lime contaminated with clay. Falſe marle.

Species VIII. Aerated lime, contaminated with ſiliceous earth. Some calcareous ſtones uſed by maſons, and certain marbles, are obſerved to give fire with the ſteel, by reaſon of the fragments of quartz they contain.

Species IX. Aerated lime, contaminated with argillaceous and ſiliceous earths. Perfect marle.

Species X. Aerated lime, contaminated with iron and magneſia; falſe white iron ore; pulverulent and black, or hard and red, or whitiſh. The mines of Halleſors afford theſe varieties.

Magneſia.

Species I. Pure magneſia; always produced by art.

Species II. Aerated magneſia; found diſſolved in waters impregnated with aerial acid.

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† The word *contaminated (inquinatus)* is uſed by Bergman to denote a ſimple mixture of two or more earths, without a true combination. We have therefore ſubſtituted occaſionally the word *mixed* in its place. The author.

Species III. Aerated magneſia, mixed with ſiliceous earth. It is ſcintillant and effervescent.

Species IV. Magneſia intimately combined with ſiliceous earth and clay; ſteatites, Briançon chalk, ſoap ſtone, lapis ollaris, ſerpentine, lapis nephriticus.

Species V. Magneſia united to a conſiderable portion of ſiliceous earth with a ſmaller quantity of calcareous and argillaceous earths, and contaminated by calx of iron. Mountain cork; mountain leather; amianthus. Bergman found in a centenary of amianthus, 64 parts of ſiliceous earth, 18. 6 of magneſia, 6. 9 of lime, 6 of vitriolated ponderous earth, 3. 3 of clay, and 1. 2 of calx of iron: and the ſame quantity of aſbeſtos afforded 67 parts ſilex, 16. 8 of magneſia, 6 of clay, 6 of lime, and 4. 2 of calx of iron.

Species VI. Magneſia mixed with argillaceous and ſiliceous earths and pyrites; a ſpecies of alum ore deſcribed and analyſed by M. Monnet (Syſt. de Minéralogie, genre 9. pag. 161.)

Species VII. Magneſia mixed with argillaceous and ſiliceous earths, together with petroleum and pyrites; magneſian aluminous ſhiſtus.

Clay.

Species I. Pure clay; it is precipitated from alum by the aerated volatile alkali.

Species II. Clay mixed with ſiliceous earth. Porcelain clay, kaolin of the Chineſe. Solid clay of Saint-Iriez in Limouſin, of Japan and of Saxony. Pulverulent clay of Weſtmanland, of Boſerup, and of China. Theſe earths are often mixed with mica. The clays uſed in the more ordinary kinds of pottery are coarſer, but of the ſame nature.

Species III. Clay mixed with ſiliceous earth and iron. Boles or bolar earths, grey, yellow, red, brown, or black. They are waſhed, in order to make the ſealed earths. The common clays of a green, blue, and red colour, are of this ſpecies.

Species IV. Clay mixed with ſiliceous and calcareous earth. Argillaceous marle; tobacco-pipe clay; agaric mineral or foſſil.

Species V. Clay mixed with ſiliceous and magneſian earth. Lemnian earth;

fuller's earth; ſoap-rock; ſmectites. Bergman has obtained from the Lemnian earth, the Hampſhire clay, and the fuller's earth of England, a large portion of ſiliceous earth, about $\frac{1}{5}$ of clay and aerated lime, and $\frac{1}{20}$ of aerated magneſia and calx of iron. He gives the generic name of lithomarga to theſe earths.

Species VI. Clay contaminated with ſulphur and vegetable alkali. Alum ore of Tolfa and Solfatara. Bergman conſiders it as a volcanic product.

Species VII. Clay mixed with ſiliceous earth, pyrites, and petroleum. Aluminous ſhiſtus. It is found in Italy, in the province of Liege, in Sweden, and in Jemtland. The black crayons, ſuch as thoſe from Bechel near Seez in Normandy, and the ampelites, are of this ſpecies. The tripolis are an aluminous ſhiſtus more or leſs burnt. Such are thoſe of Poligné in Normandy, and of Menat in Auvergne.

M. Mongez reckons in this ſpecies the ſhiſti, which contain clay in a large proportion, and more or leſs of ſiliceous earth and bitumen. The greater number are mixed with calcareous earth, and efferveſce with acids. The proportions of theſe principles vary greatly in the different ſhiſti. There are ſome of ſo bituminous a nature, that they burn with a flame; others are loaded with pyrites, and effervesſce in the air; and others are very hard, and give fire with the ſteel. M. Mongez admits five varieties. 1. The hard argillaceous ſhiſtus, or writing ſlate. 2. The ſoft argillaceous ſhiſtus, or roof ſlate. 3. The ſoft ſiliceous ſhiſtus, or poliſhing ſtone for metals. 4. The hard ſiliceous ſhiſtus, or ſtone for ſetting razors. 5. The hard calcareous ſhiſtus, which makes a bad lime; as that of Allevard in Dauphiny.

Species VIII. Clay combined with leſs than half its weight of ſiliceous earth, a ſmall portion of aerated lime and calx of iron; cryſtal gems. The happy reſearches of Bergman into the nature of gems, whoſe exceſſive hardneſs and immutability ſeem to defend them from the operations neceſſary to their chemical analyſis, have been confirmed by the labours of Margraaf, Gerhard, and Achard. Here follows the reſults of Bergman's analyſis of five cryſtal gems, which are varieties of the ſpecies we are now attending to:

	Clay.	Silex.	Lime.	Iron.
Oriental emerald contains	60	24	8	6
Oriental ſapphire	58	35	5	2
Saxon topaz —	46	39	8	6

	Clay.	Silex.	Lime.	Iron.
Oriental hyacinth	40	25	20	13
Oriental ruby —	40	39	9	10

The methods which this celebrated chemiſt has put in practice in order to obtain a knowledge of the component principles of theſe ſtones, are very ingenious, and at the ſame time very ſimple. (See Bergman's Eſſays in Engliſh, London, 1784.)

Species IX. Clay combined with ſiliceous earth, compoſing more than half of the total, weight with a very ſmall quantity of aerated lime and iron, garnet; ſchorl; tourmalin. The proportion of iron varies in theſe ſtones. (See the Analyſis of the Tourmalin of Tyrol, by M. Muller; Journal de Phyſique, vol. xv. p. 182. ann. 1780.)

Species X. Clay ſlightly united with ſiliceous earth, compoſing the half of the weight, and ſometimes more, together with a ſmall proportion of lime; zeolite. M. Mongez conſiders the azure ſtone, lapis lazuli, as a zeolite. M. Margraaf has found a ſmall quantity of gypſum ready formed in the lapis lazuli.

Species XI. Clay united to much ſiliceous earth, and a little magneſia; talc; mica. The proportion of the principles which compoſe this ſtone have not been exactly aſcertained.

Siliceous Earth.

Species I. Pure ſiliceous earth. It is prepared by fuſing clear quartz with four parts of fixed alkali, diſſolving the whole in diſtilled water, and precipitating the earth by an acid. This earth is to be well waſhed and dried.

Species II. Siliceous earth united to a very ſmall proportion of calcareous and argillaceous earth. Rock cryſtal with its varieties; quartz and its varieties; grit-ſtone and its varieties.

Species III. Siliceous earth united with argillaceous earth. Calcedony hydrophanes, or oculus mundi; this contains more clay than ſiliceous earth, according to M. Gerhard of Berlin. Opal; M. Mongez conſiders as varieties of this ſtone, the cat's eye, the fiſh's eye, and the giraſol; to theſe three ſorts of ſtones he adds the agate, and its varieties; the cacholong, the cornelian, the ſardonyx, the gunflint, the jade. Their analyſis has not yet been made with much exactneſs.

Species IV. Siliceous earth united to a very martial clay; jaſper. M. Mongez reckons the ſinople as a variety of jaſper.

Species V. Siliceous earth rendered heavy by martial earth. Falſe jaſper. M. Mongez calls this ſtone metallic quartz. He diſtinguiſhes it into the black coloured by iron, and the red coloured by copper.

Species VI. Siliceous earth united to argillaceous earth, and a ſmall portion of lime; petroſilex. This ſtone ſometimes gives ſparks with the ſteel, and effervefces with acids; it melts in a ſtrong fire.

Species VII. Siliceous earth united to clay, and a ſmall portion of magneſia; feldt-ſpar. It changes colour in the fire, and melts. It does not become decompoſed by air; it gives ſparks with the ſteel, and breaks eaſily.

Species VIII. Siliceous earth united to magneſia, aerated and fluorated lime, with the calces of iron and of copper. Praſe, chryſopraſe. It is from the analyſis of M. Achard, that Bergman deſcribes the compoſition of this ſtone.

I. A P-

I. APPENDIX.

Bergman, in his firſt appendix, treats of minerals united, or mechanically mixed with each other, in ſuch a manner, as that the parts may be diſtinguiſhed by the eye. We ſhall here mention only the mixtures of earths. Such are the ſtones called rocks, ſaxa. M. Mongez diſtinguiſhes theſe ſtones or rocks into two genera. 1. Such as have not their parts united by means of any cement, but adhering ſimply by juxta poſition, being formed by various fragments agglutinated together. He diſtinguiſhes them into three ſpecies, granite, gneis of Saxony, and hornſtone. 2. The mixed ſtones, whoſe parts are encruſted in a common cement, as is the caſe in four kinds, namely, porphyry, ophites or ſerpentine, breccias and puddingſtone. We ſhall, in this place, exhibit the varieties of theſe ſtones admitted by this naturaliſt.

I. GRANITE. It is formed of quartz, feldt-ſpar, mica, ſchorl, and ſteatites, mixed in different proportions, two and two, three and three, or four and four; the quartz always conſtitutes the baſe.

Variety I. Granite of two ſubſtances; granitin.

A. Quartz and feldt ſpar.

B. Quartz and ſchorl.

C. Quartz and mica.
D. Quartz and ſteatites.

Variety II. Granite of three ſubſtances.

A. Quartz, feldt-ſpar and mica. It is the moſt common, the moſt abundant, and the moſt varied of any.
B. Quartz, mica, and ſchorl.
C. Quartz, ſchorl, and ſteatites.

Variety III. Granite of four ſubſtances.

A. Quartz, feldt-ſpar, ſchorl, and mica.
B. Quartz, feldt-ſpar, ſchorl, and ſteatites.

II. GNEIS. Gneis is a mixture of quartz in grains, and mica in greater or leſs abundance, with much clay, or ſteatites which conſtitutes the baſe. This ſtone is foliated like ſhiſtus. It is ſubject to alteration and decompoſition in the air, in conſequence of the humidity which the clay abſorbs. The Alps in Dauphiny contain many varieties of gneis.

III. HORN-STONE. This ſtone is compoſed of very minute parts, among which brilliant ſpecks of mica may be diſtinguiſhed. It has an earthy aſpect, and when moiſtened, has an argillaceous ſmell. In the fire it hardens like clays, and melts into a blackiſh ſcoria, or black glaſs, if the heat be intenſe. Its colours are various. M. Mongez conſiders the trap of the Swedes as a variety of the horn-ſtone.

IV. PORPHYRY ſeems to conſiſt of a hard and fine paſte, of the nature of red jaſper, which envelopes grains either cryſtalline, or irregularly ſhaped, of quartz, of white or reddiſh feldt-ſpar, and ſometimes green or black ſchorl.

V. OPHITES. The ophites or hard ſerpentine, is a ſpecies of porphyry, whoſe cement is green, and the ſpots of a greeniſh white. Theſe are uſually longiſh in the ophites, while they are ſquare or rhomboidal in the porphyry. The thunder-ſtone is a variety of this ſpecies.

VI. BRECCIAS (from the Italian word denoting fragment). This is a mixed ſtone of an origin greatly poſterior to the preceding. It is formed by the deſtruction of the primitive mountains, and by irregular and worn pieces of ſilex, &c. united by one common cement. M. Mongez confounds the pudding-ſtones with the breccias. He gives a compound name to the latter, which indicates the nature of their fragments, and the cement which unites them. He diſtinguiſhes eight varieties. The calcareous breccia, which is the breccia properly ſo called, and the lumachello; the ſiliceo-ſiliceous breccia, or the pudding-ſtone;* the breccia with a calcareous cement, and fragments of the calcareous and ſiliceous genus; the breccia with ſiliceous cement, and fragments of the calcareous and ſiliceous genus; the arenario-ſiliceous breccia, ſuch as the griſon of Chartres; the breccia with cement and fragments of jaſper; the breccia with cement and fragments of porphyry; and the volcanic breccia.

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* According to this nomenclature, the firſt word expreſſes the nature of its cement, and the ſecond that of its fragments. The author.

II. APPENDIX.

Volcanic Products.

M. Mongez divides the volcanic products, after Bergman, into ſuch as have been formed by fire, and ſuch as owe their origin to water. The latter are nothing more than ſuch earthy ſubſtances, as have been diſſolved and ſuſpended in water, and afterwards depoſited in the neighbourhood, and among the products of volcanos; ſuch are the calcareous and ſiliceous incruſtations, as well as the zeolites frequently found in volcanic productions.

M. Mongez divides the true volcanic products into three orders. 1. Earthy ſubſtances very little changed by the fire; as calcareous matters, clays, granites, hyacinths, ſchorls, and mica. 2. Earthy ſubſtances calcined and burned; as the volcanic aſhes, or the rapillo and puzzolana, the tufa, the peperino of the Italians, the pumice ſtone, and the white earth which covers the ſolfatara. 3. Earthy ſubſtances melted, or lavas, of which he admits ſeveral ſpecies; ſpongy, compact, and ſtalactilical lavas, and volcanic glaſs. To theſe diviſions, he adds the earthy volcanic products of uncertain origin. In this order he particularly ranks the garnets, the volcanic ſchorl, and eſpecially the baſaltes, which he thinks are maſſes of trapp ſoftened by the humid vapours of volcanos, and afterwards ſlowly dried when the vapours have ceaſed.

§ III. Chemical Claſſification of Earths and Stones, by Mr. Kirwan.

M. Kirwan, a celebrated chemiſt of London, publiſhed in 1784, a mineralogical work, in which he claſſes all the bodies of the mineral kingdom according to their chemical properties or combinations. The earths and ſtones are ranked in his firſt part. After having given as the characters of theſe ſubſtances, inſipidity, dryneſs, brittleneſs, incombuſtibility, and inſolubility in leſs than one thouſand times their weight of water; like Bergman, he admits five genera of ſimple earths, the calcareous earth, ponderous earth, or barytes; magneſia, or muriatic earth; argillaceous earth, and ſiliceous earth. Under theſe genera he places, according to the chemical analyſis, all the known earth and ſtones.

CALCAREOUS GENUS.

He admits twelve Species.

Species I. Calcareous earth, uncombined with any acid; native lime of volcanos. Falconer on the Bath Waters, vol. 1. p. 156. and 257. Monnet, Mineralog. p. 515.

Species II. Calcareous earth combined with the aerial acid. The varieties arranged in two ſeries are tranſparent calcareous ſpar, opake ſpar, ſtalactites, tophi, incruſtations, petrifactions, agaric mineral or guhr, chalk, lime-ſtone, and marbles. Bayen, Journal de Phyſ. t. xi. p. 496.

Species III. Calcareous earth, combined with the vitriolic acid; gypſum, ſelenite or plaſter.* He admits two ſeries, the tranſparent and the opake.

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* We obſerve here, that M. Kirwan reckons many earthy ſalts among the ſtones; though the ſolubility of moſt of them, and of this in particular, is nearly double that of the moſt ſoluble of ſtones.

It would be ſuperfluous in this place to mention the proportions and the component parts of theſe pretended ſtones, as we ſhall ſpeak of them in the hiſtory of ſalts. For this reaſon we ſhall mention theſe proportions only in the two laſt genera of Mr. Kirwan, which we conſider as true earths. Note of the author.

Species IV. Calcareous earth combined with the ſparry acid. Fluor-ſpar, petunſe of Margraaf. Series 1. Tranſparent fluors. Series 2. Opake fluors.

Species V. Calcareous earth combined with the tungſten acid. Tungſten or heavy ſtone. Woulfe in Phil. Tranſ. for 1779, p. 26. Scheele's Eſſays, alſo De Luyart's on Wolfram.

Species VI. Aerated calcareous earth mixed with a notable proportion of magneſia. Var. 1. Compound ſpar, deſcribed by M. Woulfe. Phil. Tranſ. for 1779, p. 29. Variety 2. Creutzenwald ſtone, analyzed by M. Bayen. 13 Rozier, p. 59.

Species VII. Aerated calcareous earth mixed with a notable proportion of clay. Variety 1. Calcareous marl. Var. 2. Travertino, margodes. Ferber's Italy, p. 117. 159.

Species VIII. Aerated calcareous earth mixed with a notable proportion of ponderous earth. Barytical limeſtone or marl from Derbyſhire.

Species IX. Aerated calcareous earth mixed with a notable proportion of ſiliceous earth. Var. 1. Stellated ſpar. Var. 2. Calcareous grit, Moellon, Pierre de Liais. Monnet Mineralogie, p. 216.

Species X. Aerated calcareous earth mixed with a ſmall proportion of petrol. Swine ſtone.

Species XI. Aerated calcareous earth mixed with a notable proportion of pyrites; pyritaceous lime-ſtone, pierre de St. Ambroix, analyzed by Baron Servieres, 21 Rozier, 394. 22 Roz. 207.

Species XII. Calcareous earth mixed with a notable proportion of iron. Variety 1. Aerated calcareous earth mixed with iron. Rinman, Mem. Stockholm, 1754. Var. 2. Tungſten with iron. Cronſtedt, M. Stockholm, 1751.

To theſe twelve ſpecies of the calcareous genus, Mr. Kirwan adds ſix other ſpecies of compound ſtones, in which the calcareous genus predominates. 1. The different ſimple calcareous ſpecies mixed together; as ſelenite and chalk, vitreous ſpar and tungſten. 2. Compounds of calcareous and barytical ſpecies; ſuch as the yellowiſh ſtones from Derbyſhire, conſiſting of lumps of chalk interſperſed with nodules of ponderous ſpar. 3. Compounds of calcareous and muriatic ſpecies; ſuch as the white marble mixed with ſteatites, the pietra telchina, the verde antico. 4. Compounds of calcareous and argillaceous ſpecies, of chalk and ſhiſtus; ſuch as the green campan from the Pyrenees, the red campan, the yellow figured marble from Florence, the griotte, the amandola, the cipolin from Rome. (See Bayen's Journal de Rozin, vol. xi. p. 499. 801; and vol. xii. p. 51. 56, 57.) of chalk and mica; ſuch as the cipolin from Autun, the macigno, pietra bigia, columbina or turchina of the Italians. 5. Compounds of calcareous and ſiliceous ſpecies, ſcintillating marble, volcanic pudding ſtone. 6. Laſtly, Compounds of calcareous earth, with ſpecies of two or more genera, as the calcareous porphyry and lime-ſtone interſperſed with ſchorl and mica.

BARYTIC GENUS.

He admits ſix Species.

Species I. Ponderous earth combined with the aerial acid. From Alſton Moor in Cumberland, examined by Dr. Withering.

Species II. Barytes combined with the vitriolic acid. Ponderous ſpar.

Species III. Barytes combined with the ſparry acid. It does not exiſt in nature, but is produced by art.

Species IV. Barytes combined with the

tungſtenic acid. This an artificial product like the foregoing.

Species V. Aerated barytes mixed with a notable proportion of ſilex and iron.

Species VI. Ponderous ſpar, mixed with a notable proportion of ſilex mineral oil, and terrene ſalts. Liver ſtone, white, grey, yellow, brown, or black.

MURIATIC OR MAGNESIAN GENUS.

Mr. Kirwan reckons eight ſpecies, among which he ranges all earths or ſtones, in which magneſia predominates, and ſuch as exhibit the characters of the magneſian genus, though they may contain more ſilex than magneſia.

Species I. Magneſia combined with the aerial acid, and mixed with other earths. Var. 1. Mixed with ſilex; ſpuma maris. It is this ſubſtance the large Turkey tobacco pipes are formed of; terre à chalumeau of Canada. Var. 2. Mixed with calcareous earth and iron. Olive-coloured or blue earth found near Thionville. Var. 3. Mixed with clay, talc, and iron; greeniſh yellow from Sileſia.

Species II. Combined with the aerial

acid; above four times its weight of ſilex, and a ſmall proportion of argill. Var. 1. Steatites. Var. 2. Lapis ollaris.

Species III. Aerated magneſia combined with ſilex, calcareous earth, and a ſmall proportion of clay and of iron. Var. 1. Fibrous aſbeſtos. Var. 2. Coriaceous aſbeſtos, mountain cork.

Species IV. Aerated magneſia combined with ſilex, aerated calcareous earth, barytes, clay, and iron. Amianthus.

Species V. Pure magneſia combined with ſomething more than its own weight of ſilex, about one third clay, near one third water, and about one or two tenths of its weight of iron. Serpentine, lapis nephriticus, gabro of the Italians.

Species VI. Pure magneſia, intimately mixed with nearly twice its weight of ſilex, and leſs than its weight of clay. Venetian talc, Muſcovy talc.

Species VII. Magneſia combined with the ſparry acid. It has not been yet found in nature.

Species VIII. Magneſia combined with the tungſten acid. It is not met with in nature.

M. Kirwan adds to theſe, five other compound ſpecies, in which magneſia predominates. 1. The compounds of ſeveral muriated ſpecies among each other: ſteatites and talc, Briançon chalk; ſerpentine with ſteatites or aſbeſtos. 2. Of the muriatic and calcareous ſpecies; red, green, yellow, or black ſerpentine; with veins, or ſpots of white calcareous ſpar, potzevera; the black is the Nero di prato, and the green the verde di ſuza of the Italians. 3. Of the muriatic and barytic ſpecies mixed together; ſerpentine with veins or ſpots of ponderous ſpar. 4. Of the muriatic and argillaceous ſpecies; ſteatites mixed with clay, mica, or ſhiſtus. 5. Of the muriatic and ſiliceous ſpecies; ſerpentine with veins of quartz, feldt-ſpar, or ſchorl.

ARGILLACEOUS GENUS.

Mr. Kirwan diſtinguiſhes fourteen ſpecies in this genus.

Species I. Clay ſaturated with aerial acid. Lac lunæ, according to the analyſis of M. Schreber.

Species II. Clay combined with the aerial acid, and mixed with ſilex and water; clay, pipe clay, porcelain clay.

Species III. Clay ſaturated with the vitriolic acid; embryon alum in ſcales reſembling mica. *Beaumé.*

Species IV. Clay ſaturated with the marine acid; embryon marine alum.

Species V. Clay combined with about one part and a half of ſilex, nearly one part of magneſia, and half a part of dephlogiſticated iron; mica.

Species VI. VII. VIII. IX. Clay combined with ſiliceous, magneſian, and calcareous earths, with iron and bitumen; ſlate, blue ſhiſtus, pyritous ſhiſtus, bituminous ſhiſtus, argillaceous ſhiſtus.

Species X. Clay intimately mixed with near twice its weight of ſilex, almoſt its weight of magneſia, a ſmall proportion of calcareous earth, and almoſt its weight of ſemi-phlogiſticated calx of iron. Horn-ſtone, or horn-blende.

Species XI. Clay combined with four times its weight of ſilex, half its weight of pure calcareous earth, and ſomething more than its weight of iron. Toadſtone.

Species XII. Clay united to from upwards of two to eight times its weight of ſilex, about half its weight of lime, and from one to two times its weight of water; zeolite.

Species XIII. Clay imperfectly united to four times its weight of ſiliceous earth, and one third lava; pitch ſtone, lava.

Species XIV. Clay mixed with a notable proportion of red calx of iron, and ſometimes ſteatites; red chalk.

To theſe Mr. Kirwan adds ſix compound ſpecies, in which the argillaceous genus predominates.

SILICEOUS GENUS.

He admits twenty-ſix Species of this Genus.

Species I. Siliceous earth nearly pure; quartz, cryſtal, ſand.

Species II. Siliceous earth, with $\frac{1}{4}$ of clay, and $\frac{1}{40}$ of calcareous earth; common flint.

Species III. Siliceous earth, with $\frac{1}{4}$ or $\frac{1}{5}$ of clay, and $\frac{1}{12}$ or $\frac{1}{15}$ of calcareous earth; petroſilex, chert.

Species IV. Siliceous earth, with $\frac{1}{3}$ of argill, and $\frac{1}{6}$ or $\frac{1}{7}$ of calx of iron. Jaſper.

Species V. The finer flints mixed with various proportions of other earths and iron. Precious ſtones of the ſecond order. Agate, opal, chalcedony, onyx, cornelian, ſardonyx.

Species VI. Siliceous earth, with from

an equal, to three times its weight of argill, and from $\frac{1}{6}$ to an equal weight of calcareous earth, together with from $\frac{1}{18}$ to an equal part of iron. Precious ſtones of the firſt order, Ruby, topaz, hyacinth, emerald, ſapphire.

Species VII. Amethyſt. Its compoſition is not known.

Species VIII. Siliceous earth united to $\frac{1}{55}$ of its weight of calcareous earth, leſs of magneſia, with an exceeding ſmall proportion of iron, copper, and ſparry acid. Cryſopraſe.

Species IX. Siliceous earth, with blue martial fluor, and a ſmall proportion of gypſum. Lapis lazuli. M. Margraaf found it to contain clay, gypſum, ſilex, and iron. M. Rinman found it to contain the ſparry acid.

Species X. Jade. Mr. Kirwan ſuſpects it to conſiſt of ſilex, magneſia, and iron.

Species XI. Siliceous earth with clay, ponderous earth, and magneſia. Feldt-ſpar, petuntze, Labrador ſtone. 100 Parts of the white feldt-ſpar contain about 67 of ſiliceous earth, 14 of argillaceous, 11 of ponderous earth, and 8 of magneſia.

Species XII. Siliceous zeolite. It is found at Mæſſiberg. It differs from the common zeolite in giving fire with ſteel, which ſhews that it contains ſilex.

Species XIII. Siliceous earth, with more than one third of its weight of clay, and $\frac{1}{9}$ of calcareous earth, without iron. White garnet of Veſuvius. 100 Parts contain, according to Bergman, 55 of ſiliceous earth, 39 of clay, and 6 of calcareous earth.

Species XIV. Siliceous earth with clay, calcareous earth and iron. Garnet. According to Mr. Achard, 100 parts of this ſtone are compoſed of 48 ſiliceous earth, 30 clay, 12 calcareous earth, and 10 iron.

Species XV. Siliceous earth with much clay, about tenth of calcareous earth, and ſmall portions of iron and magneſia; ſhoerl.

Species XVI. Bar ſhoerl, ſtangen ſhoerl of the Germans, found by M. Fichtel in the Carpathian mountains, embodied in lime-ſtone, and cryſtallized in priſms. It ſlightly effervesces with acids. According to M. Bindheim, 100 parts of it contain 62 of ſilex, 21 of calcareous earth, 6 of clay, 5 of magneſia,

neſia, 2 of iron, and 3 of water.

Species XVII. Tourmalin. The proportion of the principles of the tourmalins of Tyrol, Ceylon, and Brazil, is thus exhibited by Bergman.

In one hundred parts of the		Clay.	Silex.	Calc.	Iron.
	Tourmalin of Tyrol	42	40	12	6
	———— Ceylon	39	37	15	9
	———— Brazil	50	34	11	5

Species XVIII. Baſaltes, trapp. 100 Parts contain, according to Bergman, 52 of ſiliceous earth, 15 of clay, 8 of calcareous, 2 of magneſia, and 25 of iron.

Species XIX. Rowly rag. A dark grey ſtone of a granulated ſtructure; which becomes magnetic by heat, and melts by a ſtrong fire. By expoſure to air, it acquires an ochreous cruſt. 100 Parts, according to Withering, contain 47. 5. of ſiliceous earth, 32. 5. of clay, and 20 of iron.

Species XX. Silex, clay, iron, and in moſt ſpecimens calcareous earth, melted by volcanic fires.

1. Cellular lavas, erroneouſly called pumice ſtones by ſome. They have undergone the loweſt degree of fuſion. Theſe ſtones contain from 45 to 50 per cent. of ſilex; from 15 to 20 per cent. of iron, 4 or 5 per cent. of pure calcareous earth, and the remainder clay.

2. Compact lavas. Theſe have undergone the ſecond degree of fuſion. They have few cavities, and give a clear ſound when ſtruck.

3. Vitreous lavas. Completely melted, and forming vitrifactions of different colours, generally black or aſh-coloured, rarely blue or greeniſh. M. Sauſſure has imitated all theſe ſpecies of lavas, by melting more or leſs perfectly the compound argillaceous ſpecies into which horn-ſtone enters, as the moſt copious, which he therefore calls hornrock (Voyage dans les Alpes, p. 127.)

Species XXI. Siliceous earth mixed with above one tenth of its weight of magneſia, and a ſmall portion of calcareous earth. Pumice ſtone.

Species XXII. Siliceous earth mixed with leſs than its own weight of magneſia and iron. Martial muriatic ſpar. Piſolites fount at Saint Marie aux Mines, by M. Maret.

Species XXIII. Siliceous earth, with $\frac{1}{3}$ of its weight of mild calcareous earth. Turky ſtone. It hardens with oil.

Species XXIV. Siliceous earth mixed with mild calcareous earth and iron. Rag-ſtone.

Species XXV. Arenaceous quartz conſolidated by a ſmaller proportion of calcareous or argillaceous earth, and a ſtill ſmaller of iron. Grit, which may be reduced to ſand by pounding. Sand-ſtone. Free-ſtone. Var. 1. Grit with a calcareous cement, from Fontainebleau. It effervеſces with acids. Var. 2. With an argillaceous cement. It does not effervеſce, and is uſed for building, and likewiſe to ſharpen tools, to filter water, &c.

Species XXVI. Siliceous ſand, conſolidated by ſemi-phlogiſticated calx of iron. This ſtone does not, like the foregoing, fall into ſand when powdered; it gives fire with ſteel, and does not effervеſce with acids, unleſs it contains teſtaceous particles. Its colour is uſually brown or blackiſh, but it grows reddiſh or yellowiſh, and moulders by expoſure to air. Meſſ. Edward King, and Gadd, have ſhewn that ſemi-phlogiſticated iron has the property of agglutinating earths, while the ſame metal, completely dephlogiſticated, does not poſſeſs that power.

To theſe Mr. Kirwan adds ſix other compound ſpecies, in which the ſiliceous earth predominates. The varieties referred to theſe ſpecies are compounds frequently found in mountains of ancient formation; and it is chiefly from the obſervations made by Mr. De

Sauſſure, in the Alps, that the Engliſh chemiſt eſtabliſhes the order of this ſupplement. Among theſe varieties, we find the different granits, pudding ſtones, granitello, granitier, porphyry, gneis, variolite, &c.

CHAP. IV.

Concerning the Chemical Analyſis of Earths and Stones.

NOtwithſtanding the great attention which for ſome years paſt has been paid to the analyſis of earths and ſtones, it muſt be confeſſed that we are ſtill very far from poſſeſſing a ſufficient number of well eſtabliſhed facts to ſerve as the baſis of a methodical diviſion of thoſe ſubſtances. It is for this reaſon, that the chemical methods hitherto offered to the public are ſo different from each other, and this circumſtance rendered it neceſſary to exhibit, in the preſent work, the ſyſtems of three celebrated chemiſts, though the interval between the publication of their reſpective works is by no means conſiderable.

The principal advantage derived from the labours of our cotemporaries in their inquiries into the nature of earths and ſtones, conſiſts in the diſcovery of methods for obtaining a knowledge of their principles. The methods of analyzing theſe ſubſtances is rather complicated, for which reaſon I ſhall in the preſent chapter exhibit merely its outlines. In fact, if we except the action of fire, air, and water, which may, without difficulty, be eſtimated by beginners, who have read the former part of this work, there is no part of the general proceſs which can be properly ſpoken of in this place without a degree of iregularity, by no means to be admitted in a book of ſcience: for the advantageous uſe of ſaline matters cannot be explained till the properties of thoſe bodies have been previouſly attended to. I ſhall refer the detail of the methods of decompoſing earthy ſubſtances by means of acids and alkalis to another part of this treatiſe.

When it is propoſed to examine into the chemical nature of any earth or ſtone, it is neceſſary, firſt, carefully to obſerve its phyſical properties, ſuch as its figure, colour, weight, &c. The extraneous matters, which are always more or leſs abundant, muſt then be ſeparated by waſhing, or otherwiſe, in order that the ſubſtance may be had pure and unmixed. A ſtone muſt be reduced into powder before its analyſis can be proceeded upon. The action of fire is one of the firſt teſts to which earths are commonly expoſed.

A few ounces of the ſubſtance under examination, being put into a crucible of well baked clay, or porcelain, is heated in a good furnace, ſuch as that of Macquer, or ſtill better in the potter's or glaſs-maker's furnace. It muſt be remarked, that the argillaceous earth, which conſtitutes the caſe or principal part of the crucibles employed in this operation, very often contributes greatly to the change produced by heat in the included ſubſtance. There is not, however, any method of obviating this inconvenience, which in fact is of no great conſequence in the comparative analyſis of a conſiderable number of ſtones. For ſome years paſt chemiſts have availed themſelves of the blow-pipe in the examination of mineral ſubſtances by fire, and it is certainly of advantage to employ this method as well as the other. The mineral ſubſtances are expoſed to the flame of a lamp or candle, urged by the blow-pipe, either alone or mixed together, or with the addition of certain ſalts hereafter to be deſcribed.* The apparatus deſcribed in my Memoires de Chimie, which is calculated to throw a ſtream of vital air, on ignited charcoal, and whoſe effects are ſo conſiderable, as to equal thoſe of the moſt powerful burning glaſſes, may be advantageouſly uſed in this inquiry. Theſe ſmall experiments exhibit a greater or leſs degree of fuſion, or ſome other changes of form, colour, conſiſtence, &c. which are to be very accurately deſcribed. This trial by fire muſt be repeated in earthen retorts, with receivers, and likewiſe the pneumato-chemical * apparatus, in order to collect the water, and aeriform fluids, which are diſengaged. The laſt mentioned products are not afforded, but by ſuch ſaline earthy ſubſtances as are conſidered by naturaliſts as ſtones; but as theſe are often mixed with true earths, it is proper to mention in this place the general method of examining them. The action of fire on ſtones, ſhews whether they are vitrifiable, argillaceous, or mixed; but as moſt ſtones are of the laſt mentioned kind, and may contain ſeveral different ſubſtances to the numbers of five or ſix, and thoſe in various proportions, it becomes neceſſary, in almoſt every inſtance, to make uſe of other methods to determine their compoſition: theſe proceſſes conſiſt in the application of a variety of acid and alkaline ſolvents, whoſe ſucceſſive action ſeparates the conſtituent principles.

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* See the Eſſay on the Blow-pipe, by Bergman, annexed to Mongez' Manuel du Mineralogiſte, or Cullen's Engliſh Tranſlation of Bergman.

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* For a deſcription of this apparatus, conſult the article gas in the Dictionaire de Chimie, in the treatiſe on the different kinds of air, by Sigaud de la Fond, &c. &c. T.

The action of air and of the vapour of water, on earthy ſubſtances, may likewiſe ſerve to enlarge our knowledge of their nature and principles. Some earths are not altered by theſe agents, others are divided, and by degrees changed in their form, colour, and conſiſtence: theſe phenomena take place more eſpecially in very compounded ſtones, and ſuch as contain much iron. The lixiviation or waſhing in hot or cold water ſerves, beſides, to ſhew the preſence of ſaline matters, often contained in them.

It is by theſe different methods, that modern chemiſts have ſucceeded in determining the nature and proportion of the principles, which enter into a conſiderable number of earths and ſtones. A more ample account of this ſubject will be given in our next ſection on ſaline ſubſtances.

PART II.

SECTION II.

SALINE SUBSTANCES.

CHAP. I.

Concerning Saline Subſtances in general, their Characters, Nature, and the Method of claſſing them.

THE number of ſaline ſubſtances is very conſiderable, and they poſſeſs peculiar characters, by which they are diſtinguiſhed from the ſubſtances before treated of in this work. Theſe characters are founded on certain properties, which it muſt be confeſſed are not accurately diſtinctive of their true nature: by this means the claſs of ſalts has been extended too much, the general properties being common to a great number of bodies.

Taſte and ſolubility in water, which have always been given as the characters of ſaline ſubſtances, are properties of many bodies which are not ſaline; as for example, all mucilages, whether of the vegetable or animal kingdoms: and on the contrary, theſe two properties are ſcarcely perceptible in ſeveral ſaline ſubſtances. Naturaliſts have not ſucceeded better in their definition of ſalts. The cryſtalline form and tranſparency which ſeveral authors have aſſumed as characteriſtic of this claſs, belong likewiſe to many other matters, more eſpecially earths, and are beſides wanting in ſome of the ſalts. It was therefore with great reaſon that Macquer aſſerted, that the limit between ſaline matters, and ſuch as are not ſaline, is unknown.

However, as it is neceſſary to come to ſome deciſion reſpecting theſe properties, we ſhall give a general account of them before we proceed to the particular hiſtory of each ſalt.

We admit as ſaline ſubſtances, all ſuch as poſſeſs ſeveral of the four following properties. 1. A ſtrong tendency to combination. 2. A greater or leſs degree of ſapidity. 3. A greater or leſs degree of ſolubility in water. 4. Perfect in combuſtibility. Before we examine each of theſe properties ſingly, it muſt be obſerved, that the ſaline quality of any given body is greater, the more of theſe properties it poſſeſſes, and the greater their intenſity. It muſt not, however, be concluded, that ſubſtances are not of a ſaline nature, becauſe theſe properties are ſcarcely evident in them; as it may often happen, that two ſpecies, which poſſeſs them in a very ſmall degree, exhibit them ſtill leſs when they come to be united; and there are likewiſe inſtances of the contrary effect taking place; but in theſe caſes, a more varied application of the chemical analyſis, or ſyntheſis, may ſerve to exhibit the ſaline properties more evidently.

§ 1. Concerning the tendency to combination, conſidered as a character of ſaline ſubſtances.

The greater number of ſalts have a tendency to combine with many different ſubſtances. It is among the ſalts, that the moſt active bodies, with reſpect to combination, are found; for this reaſon the chemiſts have at all times made great uſe of them, and have dignified certain ſalts with the names of ſolvents and menſtrua. This tendency to combination differs greatly in the ſeveral ſpecies of ſalts: ſome poſſeſs it in ſo intenſe a degree, that they corrode, diſſolve, or deſtroy every thing they touch, and that even the vitrifiable and quartzoſe ſtones cannot withſtand their action; ſuch are ſeveral of the pure ſalts called acids and alkalis: others, though they do not ſo ſtrongly tend to combination, nevertheleſs unite with great readineſs to ſeveral ſubſtances: and laſtly, there are ſalts which do not poſſeſs this property in any ſenſible degree; as is often obſervable in compound ſalts, whoſe principles have a ſtrong affinity with each other, and are mutually ſaturated. It is not to be wondered that ſalts are ſeldom found in nature in a ſtate of purity, when we attend to the effects of this property, of combining with various ſubſtances.

§ 2. Of Taſte conſidered as a Character of Saline Subſtances.

Sapidity has hitherto been conſidered as being ſo far peculiar to ſaline ſubſtances, that many philoſophers have concluded theſe bodies to poſſeſs it excluſively, and that they are the principle of ſapidity in all other bodies: though this opinion is not yet clearly proved, becauſe there are many bodies not at all ſaline, as for example, the metals, which have a very ſenſible taſte. But though inſtances may be urged, of certain ſaline matters which have ſcarcely any taſte, yet it cannot be denied, that the moſt eminently ſapid bodies belong to this claſs, for which reaſon we have aſſumed this property as one of the leading characters of ſalts. The ſapidity of ſaline matters varies like their other properties in the different ſpecies. In order to determine its origin, and more eſpecially the cauſe of the differences of its energy, it will be neceſſary to ſhew in what it conſiſts. By ſapidity, we commonly underſtand an impreſſion made on the organs of taſte, by which we determine the good or bad qualities of any ſubſtance with regard to ſalubrity; it is therefore a peculiar action of the ſapid body on the nerves of the tongue and palate of animals. But it may be aſked, whether this property of bodies enables them to act ſenſibly only on the nerves of the tongue, and whether it may not be equally exerted on all thoſe parts of an animal which contain nerves. They who are acquainted with the animal œconomy, cannot deny that the action, which excites the ſenſation of taſte, muſt produce its effect on any nerves whereſoever ſituated, and that it muſt be proportioned to the ſenſibility of the ſubject, and the organs to which it is applied.

In this way of conſidering ſapidity, we are naturally led to conclude, 1. That its impreſſion will be ſcarcely ſenſible on ſuch parts of bodies as contain few nerves, or whoſe nerves do not poſſeſs a conſiderable degree of ſenſibility, on account of their being covered: as on the ſkin, where they are defended by the reticular membrane and epidermis. It follows therefore, that the taſte of any ſalt muſt be very ſtrong and active, before it can act ſenſibly upon the ſkin. 2. That the impreſſion will be made with much more efficacy on theſe organs, whoſe nerves are large, numerous, and of a form proper to admit an extended contact, or more violent agitation, and whoſe epidermis is very thin, ſo as to leave the nerves almoſt uncovered. The ſuperior part of the tongue, the palate, and the whole internal ſurface of the mouth, are capable of perceiving the taſte of a great number of bodies, which make no impreſſion on the leſs ſenſible organs of the ſkin. 3. That bodies which have no taſte when applied to the ſkin, or put into the mouth, may nevertheleſs produce a conſiderable effect on parts more delicately organized, or whoſe nerves poſſeſs a greater degree of ſenſibility; as is the caſe of the ſtomach and inteſtines.

Theſe conſiderations being admitted, we may diſtinguiſh three claſſes of taſtes, and of ſapid bodies, to which all ſaline matters may be referred. The firſt claſs comprehends ſalts of the ſtrongeſt taſte, capable of acting on the ſkin; the impreſſion of this taſte is ſo ſtrong, as to cauſe very acute pain, and if its action be continued for a certain time, the organization of the ſkin is entirely deſtroyed. This taſte is cauſticity, and the ſalts which poſſeſs it are called cauſtic. The ſecond claſs comprehends thoſe whoſe ſapidity is of a mean degree of intenſity, and is not to be perceived but by the organs of taſte; theſe are commonly diſtinguiſhed by different names, as bitter, aſtringent, acid, acrid, urinous, &c. In the third claſs, we ſhall arrange ſaline ſubſtances, whoſe taſte is ſenſible only in the ſtomach and inteſtines: theſe are not numerous. It muſt be obſerved, that there are many degrees in each of theſe claſſes, by which bodies differ from each other in intenſity of taſte. Thus among cauſtic ſalts, ſome act much more ſtrongly than others; the former immediately deſtroying the organization of bodies, while the latter require a more conſiderable ſpace of time to produce the ſame effect. This obſervation applies likewiſe to the bitter, aſtringent and urinous ſalts, as well as to thoſe which have no ſenſible action but on the nerves of the ſtomach. Hence we are naturally led to the concluſion, that the ſeveral taſtes are degrees of the ſame property, from the moſt cauſtic, to that whoſe action is too feeble to be perceived, but on the highly ſenſible organs of the ſtomach; and this reflection ſeems to ſhew, that all taſtes owe their origin to one and the ſame cauſe.

To determine the cauſe of ſapidity, it will be proper to conſider its ſtrongeſt degree, that we may better diſtinguiſh the phenomena, and deduce its mode of action; the inquiry therefore relates to the cauſe of cauſticity; a property which has always been a ſubject of conjecture among chemiſts. Lemery obſerving that very hot bodies are exceſſively cauſtic; and likewiſe, that ſuch ſalts, as poſſeſs this property, have been ſubjected to a ſtrong degree of heat in their preparation, attributed the property of cauſticity to the particles of fire, which he ſuppoſed to be depoſited among the particles of bodies. Mr. Baumé eſpouſed this opinion.

Meyer, an apothecary of Oſnaburgh, after making a ſeries of inquiries into the nature of cauſtic ſalts, conſtructed an ingenious ſyſtem, or hypotheſis, to which many chemiſts have been much attached, though at preſent it is held in no eſteem. This philoſopher attributed cauſticity to a principle which he conſidered as a compound of fire, and a peculiar acid; this he denominated cauſticum, or acidum pingue, after the ancient chemiſts. He purſued this principle through its tranſitions and combinations, as Stahl had done before with his phlogiſton; but his ſyſtem was defective in the ſame manner as that of Stahl, as he did not ſucceed better in proving the exiſtence of his cauſticum, than Stahl did that of his phlogiſton. Dr. Black, whoſe reſearches were directed to the ſame ſubjects as thoſe of Meyer, gave the finiſhing ſtroke to his doctrine, by clearly ſhewing, that the cauſticity of lime and alkalis, far from being owing to the addition of any principle, as Meyer thought, ariſes, on the contrary, from the ſubſtraction of an elaſtic fluid, which we ſhall hereafter deſcribe under the name of the cretaceous acid.

Macquer is beyond controverſy the chemiſt, whoſe inquiries into the cauſe of cauſticity have been attended with the greateſt ſucceſs. The doctrine explained by him on this ſubject, in his Chemical Dictionary, is ſo clear, and eſtabliſhed on ſuch concluſive facts, that it is impoſſible to forbear aſſenting to his opinion. After obſerving that cauſtic bodies corrode and deſtroy our organs, by combining with their conſtituent principles, he remarks, that in proportion as this combination proceeds, the cauſtic body by degrees loſes its force, and that it ceaſes to be ſuch, as ſoon as it has diſſolved as much of the animal matter as it is capable of uniting with. Thus it is that the pure fixed alkali, or lapis cauſticus, corrodes the ſkin on which it is applied, and after a certain time becomes ſaturated, and ceaſes to act. Cauſticity therefore depends on the tendency to combination, and the effect of this force on our organs, is merely the reſult of a combination of the cauſtic matter with the matter of which the organs are formed; in the ſame manner as cauſtic bodies loſe their efficacy, when combined with any other ſubſtance with which they have a tendency to unite. The moſt taſteleſs ſalt owes its want of cauſticity, to its being already ſaturated with ſome other ſubſtance, and its taſte will be rendered ſtronger, by the ſeparation of that ſubſtance, as the whole ſeries of chemical facts evinces.

§ 3. Concerning Solubility, conſidered as a Character of Saline Bodies.

Solubility in water has been aſſumed by all chemiſts, as one of the leading properties of ſalts. Yet this property, like that of taſte, or the tendency to combination, is ſubject to great varieties. In ſome ſalts it is ſo powerful, that they cannot be deprived of the laſt portions of water they contain, but by elaborate proceſſes long continued. Others have only a mean degree of ſolubility, which may be aſcertained with conſiderable accuracy, as is the caſe with the neutral ſalts. And laſtly, there are certain ſaline matters, which are ſo little ſoluble, that they even ſeem in this reſpect to belong to the claſs of earths, and have in fact been conſidered as ſuch by naturaliſts. The limits between thoſe two claſſes of mineral bodies are very difficult to be determined, and chemiſts are not agreed on this head. Mr. Kirwan, in his mineralogy, appears to have adopted the opinion of Bergman, who thinks that all ſubſtances, which require more than one thouſand parts of water for their ſolution, ought to be ranked among earths; and that all, which are more ſoluble, ought to be eſteemed as ſalts. If this propoſition ſhould be received among chemiſts, as I think it deſerves to be, we ſhall avoid the diverſity of opinions and of language, which has hitherto prevailed, to the diſcouragement and hindrance of ſuch as enter into the ſtudy of this ſcience.

There is the ſame correſpondence between the taſte and ſolubility of ſalts, as there is between this laſt property, and the tendency to combination. For the ſolubility in water is an immediate conſequence of the tendency to combination, and muſt therefore follow the ſame laws. It is found, that the more taſte and activity any ſalt poſſeſſes, the more ſoluble it is in water, and this general fact depends on their reſpective nature and properties.

§ 4. Of Incombuſtibility, conſidered as a Character of Saline Bodies.

It is more difficult to acquire a clear idea of this property of ſaline bodies, than the others we have been ſpeaking of. They have not yet been conſidered by any chemiſt in this point of view; and many writers have aſſerted, that ſome ſalts, and among them nitre, are truly combuſtible.

To ſhew the fallacy of this opinion, and to prove that all mineral ſalts are perfectly incombuſtible, would require a more intimate knowledge of the properties of theſe ſubſtances, than the reader can yet be ſuppoſed to poſſeſs. Yet as we are of opinion, that this character of ſalts is one of the moſt evident, and the moſt neceſſary to be known, it will be proper in this place to exhibit a ſhort account of the doctrine we hold reſpecting it, which will be explained, and incontrovertibly eſtabliſhed in the accounts we ſhall hereafter give of the reſpective ſaline ſubſtances. The valuable experiments of Mr. Lavoiſier ſhew, that many combuſtible matters afford a reſidue after combuſtion, conſiſting of an acid of a peculiar nature. Combuſtion, as we have already explained, is nothing more than a combination of the baſe of vital air with combuſtible bodies. All bodies which have been burned, or are combined with the baſe of air, enter into the claſs of incombuſtible bodies; or which is the ſame thing, their tendency to combine with this baſe being ſatisfied, they are no longer capable of paſſing through the proceſs a ſecond time. Theſe principles being once admitted, if it be found that many ſalts are the reſidues of various combuſtible matters which have been burned; and moreover, if all ſalts are found to contain the baſe of pure air, and poſſeſs the characters of ſubſtances which have paſſed through the proceſs of combination, it will eaſily be conceived that they cannot be combuſtible. Theſe aſſertions are founded on a great number of facts, as will hereafter be ſeen; and they evince that ſalts are very compounded ſubſtances, moſt of them being formed by the union of certain combuſtible bodies with the baſe of pure air. And it will likewiſe be underſtood with equal facility, that this character of incombuſtibility may be conſidered as the moſt certain and invariable property of ſaline matters. The complete proof of the important aſſertions here thrown out, will, we hope, appear in the moſt ſatiſfactory manner in thoſe parts of our work, wherein we can with propriety enter more largely into this ſubject.

It muſt be confeſſed, that there are ſeveral ſalts, to which we cannot apply our reaſoning in ſo concluſive a manner; but of theſe we may make the ſame inferences by analogy, as the force of facts compels us to do reſpecting the others: and this analogy gives us reaſon to expect, that it will not be long before every part of this theory will be firmly eſtabliſhed upon experimental proof.

§ 5. Concerning the Nature and Compoſition of Saline Subſtances in general.

Stahl, who paid great attention to the nature of ſaline bodies, was of opinion that they are formed of water and earth. He collected every fact which was known in his time, and applied them to the illuſtration of his ſublime theory. But that period of improvement has been ſucceeded by another, in which, by the multiplicity of experiments, and the magnitude of the diſcoveries, concerning the influence of air in chemical phenomena, the theory of ſalts as invented by Stahl, and explained with great perſpicuity by Macquer, is no longer found adequate to the explanation of the nature and compoſition of thoſe bodies.

Though the chemical nature of ſalts is not yet perfectly underſtood, and the general facts will not permit us to aſſert, that one ſingle principle is the cauſe and origin of all ſaline bodies, as many eminent philoſophers have thought; yet it muſt be admitted, that we are better acquainted with their compoſition than formerly. It is known that they, for the moſt part, contain a very great quantity of vital air, and that this fluid is fixed in combination with combuſtible matter, of a different nature in the different kinds of ſalts. There are ſufficient proofs that many acids are thus compoſed; and it may be ſtrongly preſumed by analogy, that alkalis are compounded nearly in the ſame manner. As to the matter of fire admitted to exiſt in ſalts by many chemiſts, there is too much uncertainty reſpecting its nature, and even its exiſtence, to juſtify the adoption of any decided opinion. Laſtly, the preſence of earth in ſalts, is not ſhewn by any direct experiment. It is true that all ſalts, as found in nature, are vitiated by the addition of earthy matter; but this is merely accidental, and by no means a neceſſary or eſſential component part. All that is at preſent known concerning the general principles of ſaline bodies therefore is, that they contain vital air united to combuſtible bodies; that ſalts are moſtly the reſidues of bodies which have ſuffered combuſtion; and that the proportion of theſe two bodies, and of courſe the properties thence reſulting, are ſuſceptible of great variation. Every doctrine laid down in treatiſes of chemiſtry, reſpecting the compoſition of ſalts in general, muſt amount to nothing more than is here given; or if it proceed further, it muſt be entirely hypothetical, and moſt probably falſe.

§ 6. Concerning the Diſtribution, or Methodical Diviſion of Mineral Salts.

Thoſe ſalts, which belong to the mineral kingdom, are very numerous; many of them are the products of nature, and are formed by the action of fire, water, and air, and by the deſtruction of organized bodies; the greater number however are formed by art, or at leaſt have not yet been found among natural products. The methodical treatment of theſe ſubſtances, requires that they ſhould be divided into orders, genera, and ſpecies, as has been already done with earths and ſtones; we ſhall claſs all mineral ſaline matters into two orders.

The firſt contains ſuch ſaline ſubſtances as are reckoned ſimple; we have called them primitive ſalts, becauſe they ſerve to compoſe the ſalts of the ſecond order. The following order contains ſecondary, compound, or neutral ſalts, which are formed by the mutual combination of the ſimple ſalts.

Each of theſe orders is divided into genera and ſpecies; the mineral kingdom, as far as our preſent knowledge extends, contains nine genera, and fifty-four ſpecies of ſalts, either ſimple or compound; this number will be much more conſiderable, when certain ſubſtances, lately examined, ſhall be better known, as we ſhall obſerve at the end of this ſection.

CHAP. II.

Concerning the three Salino-terreſtrial Subſtances.

Order I. Simple or Primitive Salts.

WE diſtinguiſh thoſe ſalts by the name of ſimple or primitive, which were formerly thought to be ſo by all chemiſts; but as accurate experiments have proved that they are for the moſt part compounded, we muſt here take notice, that they cannot with propriety be called ſimple, except when compared with the ſalts of the ſecond order: the epithet primitive is more accurate, becauſe theſe compoſe, when united, the ſalts which we call ſecondary. We divide this order into three genera, comprehending ſaline terreſtrial ſubſtances, alkalis, and acids. The preſent chapter contains an account of the former, and is followed in the ſucceeding chapters by the hiſtory of acids and alkalis.

Genus I. Salino-terreſtrial Subſtances.

The three ſubſtances which compoſe this genus have hitherto been conſidered as earths, whoſe characters manifeſtly reſemble thoſe of ſalts.

The obvious ſaline properties they exhibit, together with the properties of earths, in a leſs evident degree than either the ſiliceous or argillaceous earths, has induced us to place them before the ſalts, that they may ſerve as a connecting link between the latter and earths, from which they likewiſe differ, in their much ſtronger tendency to combination.

It muſt be obſerved, that the ſalino-terreſtrial matters, as well as the primitive ſalts, concerning which we are about to ſpeak, are ſuppoſed to be perfectly pure, though they are never met with in that ſtate without previous artificial proceſſes. Of theſe proceſſes, however, we cannot yet ſpeak conſiſtently with regularity; the hiſtory of neutral ſalts will ſhew the chemical methods of decompoſing them, as well as the ſimple or primitive ſalts.

This firſt genus contains three ſpecies.

Species I. Ponderous Earth.

Ponderous earth received its name from Meſſrs. Gahn and Scheele, Swediſh chemiſts, who firſt diſcovered its combination with the vitriolic acid, with which it forms a very ponderous ſalt. M. de Morveau calls it barote, which Bergman has tranſlated into

Latin, by the term barytes; its ſpecific gravity exceeds 4000, according to Kirwan. This earth is never found in a ſtate of purity: Meſſrs. Margraaf and Monnet imagined it to be of the nature of abſorbent or calcareous earth. The latter, however, obſerved that it poſſeſſes certain peculiar properties, and was inclined to conſider it as a peculiar earth. It has not hitherto been much examined in its uncombined ſtate. The compounds it forms with acids, and its affinities, afford the means of diſtinguiſhing it from every other ſubſtance.

Pure ponderous earth obtained by the methods hereafter to be deſcribed, is of a pulverulent form, extremely fine, and of a white colour. I have not obſerved that it impreſſes the ſenſe of any peculiar taſte on the tongue.

It is not yet known whether the action of light alters its colour.

The ordinary fire of our furnaces is inſufficient to melt it; it communicates a blue or greeniſh colour to the crucible in which it is heated, and is itſelf lightly tinged with the ſame colour: a property that appears to depend on the mutual action exerted between this earth and clay. Mr. D'Arcet aſſerts, that a very violent heat melts it in a crucible either of clay or iron. Expoſed to the air, its weight increaſes, and it combines, though very ſlowly, with the cretaceous acid of the atmoſphere;

moſphere; the effect of vital air on this ſubſtance is not known.

It is ſoluble in water, though very ſparingly, 900 parts of the fluid being required to ſuſpend one part of ponderous earth. Water, thus ſaturated, gives a ſable green colour to the tincture of violets.* This ſolution expoſed to the air becomes covered with a thin pellicle, which if taken away, is from time to time renewed; the cretaceous acid contained in the atmoſphere combining with the ponderous earth, and cauſing this phenomenon, which is ſimilar to what happens with lime-water in like circumſtances. The ſame ſolution, evaporated to dryneſs, leaves the ponderous earth, from whoſe weight the ſolubility of this ſubſtance may be eſtimated. The neceſſity of uſing diſtilled water in this, as well as in every chemical proceſs where accuracy is required, is ſufficiently obvious.

Ponderous earth has no ſenſible action either in the dry or humid way on ſiliceous or argillaceous earth.†

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* Tincture of violets is a ſolution of the colouring matter of theſe flowers in water; the freſh, or newly made tincture, is a much nicer teſt than the ſyrup of violets; but as the ſyrup may be employed in many caſes to exhibit the preſence of ſaline matter, we ſhall have frequent occaſion to mention it inſtead of the tincture. F.

† It is proper to obſerve in this place, that for the ſake of order, I do not ſpeak of the combination of two bodies till

This ſalino-terreſtrial ſubſtance is found leſs abundantly in nature than either of the others of that deſcription. Some modern chemiſts ſuppoſe it to be a metallic calx, as Bergman long ſince ſuſpected from its weight, and that of the compounds into which it enters, as well as from the precipitate it forms, when the Pruſſian alkali is added to its acid ſolution. It is aſſerted that Mr. Gahn, a diſciple of this celebrated chemiſt, has ſucceeded in obtaining this ſubſtance in the form of a regulus; but the fact requires confirmation. Its intimate nature is yet unknown; as no one has ſucceeded either in ſeparating its principles, or imitating it by compoſition.

Ponderous earth, in a ſtate of purity, has not been applied to any uſeful purpoſe; its ſolutions in acids are employed as re-agents, as will be more fully ſhewn hereafter.

Species II. Magneſia.

Magneſia is uſually obtained from Epſom

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till each has been firſt ſingly deſcribed. In conformity with this rule, I have not in the hiſtory of ponderous earth taken notice of the changes it ſuffers by combination with other bodies, except light, fire, air, water, vitrifiable and argillaceous earths; becauſe theſe are the only ſubſtances yet treated of: its other combinations will therefore be treated of as we advance. This order poſſeſſes the double advantage of being very methodical, and of facilitating the progreſs of the learner. F.

ſalt, and abounds in the mother water of nitre, and in a great number of ſtones, &c. It is not found pure in nature, but almoſt always in combination with an acid. Black is the firſt chemiſt who made an accurate diſtinction between this ſubſtance and lime.

Magneſia obtained in a ſtate of purity by the methods to be deſcribed in future, is in the form of a very fine powder, conſiderably reſembling flour in its appearance and feel; its ſpecific gravity is about 2,33, according to Kirwan; it has no ſenſible taſte on the tongue, but appears to act on the ſtomach, for it is a ſlight purgative; it gives a faint greeniſh colour to the tincture of violets, and converts turnſole to a blue. The action of light on magneſia has not been accurately noticed, but it does not appear to be conſiderable. When expoſed to a violent heat it does not melt, according to the experiments of M. D'Arcet. Macquer has obſerved likewiſe, that it remains unchanged in the focus of the burning lens of the garden De L'Infante. M. De Morveau obſerved the ſame reſult, after expoſing magneſia for two hours to the moſt violent heat of Macquer's furnace. Mr. Butini, who has publiſhed a ſet of valuable inquiries into the nature of the magneſia of Epſom ſalt, has obſerved that this ſubſtance contracts in its dimenſions by a ſtrong heat, ſo that its particles become ſufficiently hard to ſcratch iron. It is alſo affirmed that a ſmall cube formed out of a paſte of magneſia and water, expoſed to the focus of Parker's lens, contracted ſuddenly in all its dimenſions: this property ſhould ſeem to point out ſome reſemblance between magneſia and clay, with which it is often found naturally combined, as has been obſerved in the hiſtory of ſteatites, aſbeſtos, ſerpentine, &c.

Magneſia heated in a retort loſes nothing but the water it contained; but at the ſame time it acquires a conſiderable degree of phoſphoreſcence, as Mr. Tingry, apothecary at Geneva, has obſerved. Expoſed to the air, it remains long without alteration. M. Butini placed 10 grains of calcined magneſia in a porcelain ſaucer covered with a paper in a dry chamber, and after near two years it had gained no more in weight than about the eighth of a grain. It appears to combine very ſlowly with the cretaceous acid of the atmoſphere. It is very ſparingly ſoluble in water: 4 ounces and a quarter of pure water being left in a bottle for three months, together with one eighth of an ounce of calcined magneſia, firſt boiled together with the fluid, afforded M. Butini a reſidue by evaporation, which he eſtimated to be the one fourth of a grain.

Mr. Kirwan aſſerts, that it requires 7692 times its weight of water to diſſolve it in the ordinary temperature of the atmoſphere;

that is to ſay, about 60 degrees of Fahrenheit's thermometer. Notwithſtanding this difficulty of ſolution, magneſia forms a kind of paſte with water. This paſte is not ductile, but is eaſily broken, and the water is ſoon ſeparated either by heat, or the contact of dry air: the ſolution of magneſia has no ſenſible taſte, and ſcarcely alters the colour of ſyrup of violets.

The action of magneſia on the pure earths is not yet well known; it is decided, however, that it cannot be fuſed with either the ſiliceous or argillaceous earths ſingly, but it may with both together.

The mutual action between this and the ponderous earth has not been inquired into.

The intimate nature of magneſia is not more known than that of ponderous earth; there is no experiment which can be urged to prove that it is a modification of any other earthy or ſaline ſubſtance, as certain chemiſts have imagined. No one has yet ſucceeded in ſeparating magneſia into its component parts; neither has it yet been formed by ſyntheſis: in the preſent ſtate of chemiſtry it muſt therefore be conſidered as a ſimple ſubſtance.

Pure magneſia, which Dr. Black calls cauſtic, is employed in medicine, as an abſorbent and purgative. It is to be preferred to the ordinary magneſia in thoſe caſes wherein acidities abound, becauſe the cretaceous

ceous acid contained in the latter is diſengaged by the acids in the firſt paſſages, and produces flatulences, with all their numerous attendant conſequences: it preſerves fleſh for a long time, and even reſtores putrified bile. Mr. Bergman attributes to it the property of rendering camphor, opium, reſins, and gum reſins, ſoluble in water; though pure magneſia, as we have obſerved, is itſelf ſcarcely ſoluble in that fluid: theſe preparations of Bergman are unknown in France.

Species III. Quick Lime.

Quick lime is a white ſubſtance, whoſe parts cohere more ſtrongly together than thoſe of the two ſubſtances laſt treated of; it is uſually in the form of a ſtone, of a dirty white; its taſte is burning, acrid, and urinous; and is ſufficiently ſtrong to cauſe inflammation when applied to the ſkin; its ſpecific gravity is about 2,3, and it is pulverulent and friable. It is found native in the vicinity of volcanos, as Mr. Monnet obſerved among the mountains of Auvérgne.

Lime converts the ſyrup of violets to a much deeper green than is produced either by ponderous earth or magneſia; it even almoſt deſtroys this colour, and converts it it into a dirty yellow.

Lime expoſed to a very violent heat, as for example, that of a glaſs-houſe, ſuffers no alteration. Parker's burning glaſs, however, appears to have produced a ſlight commencement of fuſion, though the lime was placed on a ſupport of charcoal: its extremities are ſometimes melted when expoſed to a ſtrong heat in a crucible of clay; but this effect is produced by the mutual action of the two earths on each other.

Lime expoſed to the air ſwells, breaks, and is reduced to powder, its bulk being conſiderably increaſed: it is then called lime ſlaked in the air. This change takes place more quickly, accordingly as the air is more humid; it is attended with heat, and the dilatation is ſufficiently ſtrong to burſt caſks in which lime is contained. If this ſubſtance be examined after being ſlaked, by expoſure to air, it is found to conſiſt of a very fine white powder, remarkably increaſed in weight, while the intenſity of its taſte is diminiſhed. This change is principally owing to the water contained in the atmoſphere, which has a ſtrong tendency to unite with the lime: if ſlaked lime be heated in a retort, it returns to its original ſtate. The action of water on quick lime is very ſtrong. When a ſmall quantity of this fluid is poured on lime it is quickly abſorbed, the lime appearing as dry as before: after a ſhort interval of time it burſts into pieces, producing a degree of heat ſufficient to reduce the water into vapours, with a remarkable hiſſing noiſe. Theſe vapours appear in the form of a white ſmoke, and have a peculiar ſmell: the lime ſoon falls into a white powder; the heat, the agitation, and the vapours gradually diſappearing. If this extinction be made during the night, or in a dark place, many luminous points are obſerved on the ſurface of the lime. All theſe phenomena are conſequences of the activity with which this ſalino-terreſtrial ſubſtance unites with water; but in order that they may take place, it is required that no more water be uſed than the lime can very quickly abſorb, ſo as to become immediately dry. It ſeems that the diſengagement of heat from theſe two bodies changes their ſtate, and that ſlaked lime in its pulverulent form, contains water in a dry and ſolid ſtate. This dry ſtate of water, which takes place in many combinations, attended with heat, and which produces ſolid compounds, whoſe ſpecific heat is leſs conſiderable than before, has not been enough attended to by chemiſts, or to ſpeak more properly, has been totally unobſerved till lately. When lime, in this experiment, has abſorbed as much water as it can combine with and remain dry, it is called dry ſlaked lime; it then no longer produces heat by the addition of water, but is diſſolved without any ſenſible motion, if the quantity of water be conſiderable. The white opake fluid, or mixture, is called milk of lime; if the quantity of water be ſtill greater, the lime is perfectly diſſolved, and the liquor becomes tranſparent. Mr. Kirwan affirms, that 680 parts of water are required to diſſolve one of lime, at the temperature of 60 degrees.

This ſolution, which is known by the name of lime-water, is clear and limpid; its ſpecific gravity ſcarcely exceeds that of common water; its taſte is acrid and urinous; and it readily converts ſyrop of violets to a green. By evaporation in cloſed veſſels, very pure water is obtained, the quick lime remaining behind; but a red heat is neceſſary to ſeparate the laſt portions of water, which are retained with great force: after this treatment, the lime becomes heated by the addition of ſmall quantities of water as before.

Lime-water expoſed to the air becomes covered by a dry pellicle, which gradually increaſes in thickneſs and ſolidity: if this pellicle be taken away, a ſecond is formed, and after that a third, and ſo forth, till the whole of the water is evaporated. Theſe pellicles have been improperly called cream of lime; it was formerly thought to be a peculiar ſalt formed by the union of the moſt ſubtle part of the calcareous earth united to water; and much has been written concerning this pretended ſalt of lime. But it is now admitted, ſince the experiments of the celebrated Black, that the ſaline properties of cream of lime are leſs intenſe than thoſe of the lime itſelf; and that it is a peculiar neutral ſalt compoſed of lime, and an acid extracted out of the atmoſphere. We ſhall ſpeak of this ſalt under the name of chalk.

Lime combines with vitrifiable earth in the humid, as well as in the dry way. When ſand is mixed with lime newly ſlaked, or with quick lime ſprinkled with a ſmall quantity of water at the time of mixing, theſe two bodies become conſiſtent, and form what is called mortar. The ſtate and quantity of the lime, as it is more or leſs perfectly calcined; its previous ſlaking, with a greater or leſs quantity of water, or the ſlaking of it at the time of mixture; the nature of the ſand with regard to its magnitude, its angular or round figure, as well as its degree of moiſture, produce very conſiderable differences in the ſeveral kinds of mortars. Clay baked into bricks, or pouzzalana, which is clay baked by volcanic fires, and altered by expoſure to air, are likewiſe added to lime in the making of mortar.*

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* Conſult Les recherches de M. de la Faye, ſur la preparation que les romains donnoient à la chaux, Paris 1777 & 1778, the firſt and ſecond parts. F.

Though lime, as well as ſiliceous earth, be perfectly infuſible alone; yet if they be heated together, the proportion of the former being much the greateſt, they melt, as has been obſerved by Meſſrs. D'Arcet and Gerhard. Lime likewiſe ſerves as a flux to one third of its weight of clay: it appears to have a ſtronger affinity with this earth, than with ſilex, as Kirwan informs us. The mixture of theſe three ſubſtances melts ſtill more eaſily and completely, than lime with either of them ſingly; ſo that one part of lime and one of clay, will ſerve to fuſe two parts, or even two and a half of ſiliceous earth: this fact ſhews the cauſe why many hard ſtones giving fire with ſteel, and of a quartzoſe nature, melt when expoſed to a ſtrong heat; the combination, or ſimple mixture of calcareous earth and clay, is the cauſe of their vitreſcibility.

The mutual action of lime and ponderous earth is not yet known.

One part of calcareous earth enters into fuſion with half a part of magneſia: the glaſs, formed by this mixture, afterwards diſſolves, and completely melts a quantity of ſiliceous earth, equal to the lime it contains; equal parts of ſiliceous earth, magneſia and lime, melt therefore by heat into a perfect glaſs.

The intimate nature of lime is not known. The early chemiſts, deſirous of explaining, by phyſical reaſoning, the phenomena exhibited by lime in its combinations, and more eſpecially in its extinction, referred its cauſe to the particles of fire fixed in the calcareous ſtone during its calcination. This was the theory of Lemery. M. Meyer did not admit that pure fire was capable of combining in this manner, and therefore aſſerted, that it exiſted in lime united with a peculiar acid: this ſubtle kind of ſulphur was the acidum pingue, or the cauſticum of this chemiſt; but his doctrine, though occaſionally brought forward under different names, has been overthrown by a ſeries of experiments, which have completely ſhewn its falſity. Many modern chemiſts believe, that the matter of heat exiſts in a combined ſtate in lime, and that the light perceived by Meyer and Mr. Pelletier, with the ebullition, the evaporation of the water, and the peculiar ſmell during the extinction of the lime, are conſequences of its diſengagement; but this opinion muſt continue to be merely hypothetical, till it ſhall be demonſtrated that heat, conſidered as matter, exiſts in all thoſe phenomena, which may be well explained, by conſidering it as nothing more than a modification of bodies. Theſe obſervations ſhew, that the principles and compoſition of lime are yet unknown, and that we cannot, with any certainty, decide whether it is the product of an attenuation, or peculiar preparation

tion of the vitrifiable or argillaceous earths; though that opinion appears probable to ſome of the greateſt naturaliſts. It cannot in fact be doubted, but that it is formed by marine animals, and that its conſtituent parts are united and combined in the water, during the life of theſe organic beings; but nothing further can be added on the ſubject, which deſerves the attention of ſuch as dedicate themſelves to ſtudies which demand accuracy, and who prefer the knowledge of facts to mere ſuppoſition.

Lime is employed in a great number of arts, and eſpecially in building. In medicine, diluted lime-water is adminiſtered with ſucceſs, in the cure of ulcers, &c. it has been eſteemed as a powerful lithontriptic; but repeated trials have ſhewn, that it is not always attended with the deſired ſucceſs, and that its uſe, long continued, produces an alteration in the animal fluids of a ſcorbutic or ſeptic nature.

CHAP. III.

Genus II. Alkaline Salts.

WE place alkalis before acids, becauſe they appear to be more ſimple, leſs eaſily decompoſed, and reſemble the ſalino-terreſtrial ſubſtances in their properties. They have a urinous, burning, and cauſtic taſte; turn the ſyrup of violets to a green; give out heat on being united with water; abſorb the acid contained in the air; diſſolve earths; and have a ſtrong tendency to combination. Three ſpecies of alkalis are known; vegetable fixed alkali; mineral fixed alkali; and volatile alkali.

Species I. Vegetable fixed Alkali.

Vegetable fixed alkali is ſo denominated, becauſe it is found in large quantities in the vegetable kingdom, though it is likewiſe found in the mineral kingdom; it is uſually called ſalt of tartar, or pot-aſh, becauſe theſe two ſubſtances greatly abound with it. The vegetable fixed alkali, in a ſtate of purity, was not known before the diſcoveries of Dr. Black.

This ſalt, when pure, is dry, ſolid, and of a white colour; its taſte is ſo ſtrong, that it deſtroys the texture of the ſkin. It inſtantly converts the colour of ſyrup of violets to a much deeper green, than lime-water produces in that ſubſtance, and this green is quickly deſtroyed and converted to a brown yellow.

The action of light on the vegetable alkali is not known.

Expoſed to heat in cloſed veſſels, it ſoon becomes ſoft, and melts at the commencement of ignition; if it be then poured out on a ſmooth ſtone, or metallic plate, it concretes into an opake brittle maſs. It is not decompoſable by heat, and becauſe it is not volatalized, except in a very ſtrong heat, ſuch as that of a glaſs-houſe, it is called fixed. It diſſolves a portion of the earthen veſſels in which it is heated.

Expoſed to the air, it ſtrongly attracts humidity, becoming liquid, and gradually aſſuming the ſtate of a neutral ſalt, by combining with the acid of the atmoſphere. This is the cauſe of the augmentation of weight, and the property of effervefcing with acids, which it acquires by ſuch expoſure. To preſerve it in a ſtate of purity, it muſt be kept in well cloſed veſſels, entirely filled with it.

The vegetable fixed alkali diſſolves in water with great facility, producing at the ſame time a high degree of heat, and exhaling a fetid lixivious taſte: its ſolution is colourleſs, and affords no precipitate, when the ſalt is very pure. If it be deſired to ſeparate it from its ſolvent, the water muſt be evaporated to dryneſs, in cloſed veſſels; for if the operation be made in open veſſels, it attracts the acid contained in the air, and becomes effervefcent. This abſorption is ſo rapid, that it is ſcarcely poſſible to leave the ſolution of this ſalt expoſed to the air, without

out its being partly neutralized: the ſame alteration takes place if it be kept in a bottle, which it only fills in part, and which is often opened.

In the dry way it combines with vitreous or quartzoſe earths, and forms by fuſion the tranſparent body called glaſs. This body has different properties, according to the relative quantities of ſand, and fixed alkali it contains. If two or three parts of ſalt be uſed to one of earth, a ſoft glaſs is produced, which attracts the humidity of the air, becomes opake, and at laſt fluid. This glaſs is ſoluble in water, by virtue of the ſuperabundant alkali it contains; and the ſolution is called liquor of flints: in proceſs of time it depoſits a portion of the earth it contains, in white ſemi-tranſparent flakes, of a mucilaginous appearance, and ſo light, that they ſubſide very ſlowly. Acids ſeize the alkali, and precipitate the earth. In order that this precipitation may be well performed, the liquor of flints muſt not be too much diluted; for in this caſe the particles of earth are in a ſtate of ſuch extreme diviſion, that they remain ſuſpended in the liquid, which muſt be evaporated, before any ſenſible ſubſidence can take place. Several chemiſts think that the earth of flints, thus obtained, has been changed in conſequence of its union with alkalis; they imagine that it reſembles argillaceous earths, and is capable of uniting with acids, and forming argillaceous ſalts: this was the opinion of Pott and Beaumé, but Scheele has ſhewn, that this ſoluble portion of the earth precipitated from the liquor of flints, is obtained from the veſſel of clay in which the quartzoſe earth and alkali are fuſed.

The art of making glaſs, is a proceſs intirely chemical: the purity of the two ſubſtances, their proportion, and their complete fuſion, by the application of heat ſufficiently ſtrong and long continued, are conditions indiſpenſably neceſſary for producing glaſs, which ſhall be hard, tranſparent, without bubbles, and unalterable in the air. We ſhall hereafter have occaſion to take notice of different ſubſtances added to the ſand and alkali, to increaſe their fuſibility, and to produce glaſs of a due degree of weight, tranſparency, and other properties adapted to the uſe it is intended for.

Fixed vegetable alkali does not act ſo ſtrongly on pure clay, as on quartzoſe earth; but the difference has not been accurately aſcertained.

This ſalt appears capable of combining with ponderous earth, magneſia, and lime; but theſe combinations have not been much inquired into.

Though the vegetable alkali has not yet been decompoſed, yet there are many facts which tend to ſhew that it is not a ſimple ſubſtance. Stahl, who conſidered the ſimple ſalts as products of the union of water and earth, imagined that fixed alkali differs from acids, only in its containing the latter or earthy principle more abundantly; from this conſideration he explained its dryneſs, and other diſtinctive properties. It is probable that vegetable alkali, as well as all other ſalts, conſiſts of a combuſtible body, united with air; ſince Rouelle has obſerved, that vegetables, by burning, afford more alkali than in their natural ſtate. This alkali, in many caſes, acts like acids, which are known to contain pure air in large quantities; for it calcines metals, burns combuſtible matters, &c. We do not however propoſe this but as an hypotheſis not yet proved, though it may ſerve to explain ſeveral facts.

The vegetable fixed alkali is employed in ſurgery to corrode the ſkin, and to produce inflammation and ſuppuration in certain caſes.

Species II. Mineral fixed Alkali.

The name of mineral fixed alkali is given to a ſaline ſubſtance, which poſſeſſes the ſame general characters as the foregoing, and is found in great quantities united with a peculiar acid ſalt, in the waters of the ſea, and in many ſprings. It is likewiſe obtained from vegetables, though much leſs frequently than the preceding. This ſalt has

been

been called marine alkali, becauſe it is one of the component parts of marine or common ſalt; it is alſo called ſalt of ſoda, becauſe it is moſt frequently obtained from that plant. The mineral fixed alkali, when pure, has as ſtrong and as cauſtic a taſte as the vegetable alkali; it produces an equally intenſe green in ſyrop of violets: its form is dry and ſolid.

It melts at the commencement of ignition; a violent heat volatilizes it; it acts on almoſt every kind of veſſel in which it is heated.

Expoſed to the air of the atmoſphere, it attracts the humid vapours, as well as the aerial acid, and gradually becomes neutralized. The action of the oxyginous principle, or vital air, on this ſalt, is not known.

It diſſolves in water, producing heat, and emitting a fetid lixivial odour. Evaporation in cloſed veſſels, is the only method of recovering it in a ſtate of purity from its ſolution; and for the ſame reaſons as were mentioned in treating of the vegetable alkali, it muſt be preſerved in well cloſed veſſels entirely full.

The mineral fixed alkali combines readily with vitrifiable earths in the dry way, and forms glaſs. Glaſs-makers have obſerved, that this ſalt produces a more fuſible and ſolid glaſs that the vegetable alkali; for which reaſon they prefer it in the manufacture of that commodity. Laſtly, this alkali,

kali, like the vegetable fixed alkali, combines with acids, and with a great number of bodies hereafter to be treated of.

From theſe properties it may be obſerved, that the difference between the two fixed alkalis, in a ſtate of purity, is not very conſiderable, and that their reſpective properties can only be known with certainty, from their combinations. When united with the ſame acid they produce neutral ſalts exceedingly different in all their properties; a circumſtance which ſeems the more ſingular, as it is abſolutely impoſſible to point out any difference between them in their pure and cauſtic ſtate. Bergman adds, as a diſtinguiſhing property of theſe two ſalts, that their affinity with acids is not the ſame; that of the vegetable fixed alkali being the ſtronger, ſo that it is capable of decompoſing ſalts, whoſe baſe is the mineral alkali. This ſubject will again come under examination, when we ſpeak of ſecondary ſalts.

The intimate nature or compoſition of the mineral fixed alkali, is not more known than that of the vegetable fixed alkali.

It is uſed in the making of glaſs, ſoap, and other compounds.

Species III. Volatile Alkali.

The volatile alkali is diſtinguiſhed from the two foregoing, by its ſtrong and ſuffocating ſmell, and its ſingular volatility.

Like the fixed alkalis, this ſalt was not known in its ſtate of purity, before the ingenious experiments of Black and Prieſtley; that which was conſidered as ſuch, is a ſpecies of imperfect neutral ſalt, in a ſolid and cryſtalized form, poſſeſſing ſome of the properties of volatile alkali, but really compoſed of two ſaline ſubſtances: the character or property of effervefcing with acids, which was formerly attributed to the volatile alkali, belongs only to this neutral ſalt.

The liquid known in chemical laboratories, by the name of cauſtic, or fluor volatile alkali; and in pharmacy, by that of volatile ſpirit of ſal ammoniac; conſiſts of this alkali diſſolved in water. Dr. Prieſtley has ſhewn, that by the help of a gentle heat, this liquor may be made to give out a permanent gas; and that the water deprived of this gas, loſes its alkaline properties. This aeriform fluid is the pure volatile alkali, and is known by the name of alkaline gas. Macquer has well obſerved, that this body muſt be examined, in order to arrive at a knowledge of the properties of the volatile alkali.

To obtain this elaſtic fluid, a certain quantity of the alkaline ſpirit is put into a ſmall retort, or matraſs of glaſs. A recurved tube is adapted to this veſſel, and the extremity of the tube is plunged beneath the mercury of a pneumato-chemical apparatus; a veſſel of glaſs filled with the ſame metallic fluid, being inverted over its orifice. The bottom of the retort or matraſs is then heated, by means of burning charcoal, or the flame of ſpirit of wine. The firſt portion of elaſtic fluid, conſiſting chiefly of the common air contained in the veſſel and tube, is ſuffered to eſcape, and when the ebullition of the fluid is ſtrong, the gas is to be collected. The diſtillation muſt not be urged, ſo as to cauſe the water to paſs in the form of vapour, or a ſmall veſſel ſhould be affixed in the middle of the tube of communication, which being kept cool, may ſerve to condenſe the aqueous vapour, and cauſes the alkaline gas to paſs in a very pure and dry ſtate.

The alkaline gas, obtained by this proceſs, reſembles air in its tranſparency and elaſticity, as long as it is kept above the mercury. It is rather lighter than the air of the atmoſphere; its ſmell is penetrating, and its taſte is acrid and cauſtic; it readily and ſtrongly changes the blue colour of violets to a green, but the alteration produced, is leſs than when pure alkalis are uſed; it deſtroys animal life, and corrodes the ſkin, if expoſed for ſome time to its action.

Though it is incapable of maintaining combuſtion, and extinguiſhes bodies which are already on fire, yet it increaſes the magnitude of the flame of a taper before extinction, producing a pale yellow colour round its edge, which proves that alkaline gas is partly inflammable.

It is abſorbed by porous bodies, ſuch as charcoal, ſpunge, &c.

Prieſtley has diſcovered, that the electric ſpark paſſing through alkaline gas, increaſes its volume to three times its former quantity, and changes it into inflammable gas; the cauſe of this change is not yet known. But it ſeems that the alkaline gas is decompoſed in this operation.

Alkaline gas is one of the elaſtic fluids which are the moſt ſuſceptible of dilatation by heat.

Atmoſpheric air does not combine with alkaline gas, but only mixes with and dilutes it: the action of vital air on this gas has not yet been examined.

Water quickly abſorbs alkaline gas; if the water be frozen, it immediately becomes fluid, and produces cold; whereas, on the contrary, fluid water becomes heated by combination with this gas. Water ſaturated with gas is known by the name of fluor and cauſtic volatile alkali: we apprehend that this ſolution may be called volatile alkaline ſpirit, in the ſame manner as the ſolution of marine acid gas is called ſpirit of ſalt. We ſhall hereafter ſee that the ſtrongeſt and moſt pure alkaline ſpirit is produced by ſaturating diſtilled water with this gas.

Alkaline gas has no ſenſible action on earths, or on the ſalino-terreſtrial ſubſtances. Its action on acids, and many neutral ſalts, is very conſiderable.

The alkaline ſpirit has the ſame properties as the gas it holds in ſolution, but not in ſo eminent a degree; becauſe the gaſeous being much leſs ſtrong than the fluid aggregation, the tendency to combine, will, according to one of our laws of affinity, be much more ſtrong in the gas than in the alkaline ſpirit.

Volatile alkali has been conſidered as a combination of fixed alkali with a combuſtible ſubſtance. This conjecture was founded on the conſideration that volatile alkali is produced in many circumſtances by heating fixed alkali with inflammable matters; but it was not known whether the fixed alkali entered as a principle into the compoſition of the volatile alkali, or whether it did not afford a peculiar principle, which, by combining with a portion of combuſtible matter, produces that ſalt. Our knowledge reſpecting the nature of volatile alkali is at preſent ſomewhat more extended. The fine experiment of Dr. Prieſtley, who changed alkaline gas into inflammable gas, by the electric ſpark, has cauſed ſeveral chemiſts to ſuſpect that the latter is one of the principles of volatile alkali. Mr. Berthollet, by a ſeries of experimental inquiries, has ſucceeded in proving that this ſalt is a compoſition of aqueous inflammable gas, and atmoſpheric mephitis or phlogiſticated gas. He was led to this concluſion by the action of dephlogiſticated or aerated marine acid on the alkaline ſpirit, by the decompoſition of ammoniacal nitre in cloſed veſſels, and by the reduction of metallic calces effected by means of alkaline gas. Theſe facts will be exhibited more at length in the hiſtory of the compound ſubſtances to which they relate. We ſhall confine our obſervation in this place to the facts, that when combinations of the calces of copper and of gold are heated with alkaline gas, water and phlogiſticated gas, or atmoſpheric mephitis are obtained, and the metals are reduced. In theſe operations the volatile alkali is decompoſed, its inflammable gas ſeizes the vital air of the metallic calces with which it forms water; the metals remain pure, and the phlogiſticated gas, or atmoſpheric mephitis, the other principle of volatile alkali, is ſet at liberty. From theſe experiments, of which we ſhall, in the courſe of the preſent work, give a more ample account, Mr. Berthollet concludes, that volatile alkali contains ſix parts of atmoſpheric mephitis, and one of inflammable gas, The volatile alkali, diluted with water, is uſed in a great number of diſorders; it is aperient, and powerfully inciſive. It acts ſtrongly on the ſkin; it is preſcribed as a remedy for the bite of vipers, and for cutaneous, and venereal diſorders, &c.

As this ſubſtance is acrid and cauſtic, it ought not to be uſed, but with particular care. Externally applied, it is found exceedingly ſerviceable in diſcuſſing tumours, eſpecially ſuch as are formed by coagulated milk, lymph, &c. It readily cures burns, and is often and ſucceſsfully employed in the cure of chilblains, &c. It has been conſtantly uſed under different names, as a very active ſtimulant in ſyncopes, apoplexies, &c. Its uſe in the latter caſe ought to be in very moderate quantities; it is not prudent to adminiſter it internally, without previous dilution in a conſiderable quantity of water. Dangerous excoriations have been produced in the oeſophagus, and the membranes of the ſtomach, by the volatile alkali being given without this precaution.*

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* M. de Morveau propoſes to call the vegetable fixed alkali by the name of pot-aſh (potaſſe); the fixed mineral alkali by the name of ſoda (ſoude); and the volatile alkali by the name of ammoniac. Theſe denominations have the advantage of rendering the nomenclature of neutral ſalts uniform and eaſy. Conſult our ſecond volume. F.

END OF VOLUME THE FIRST.

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